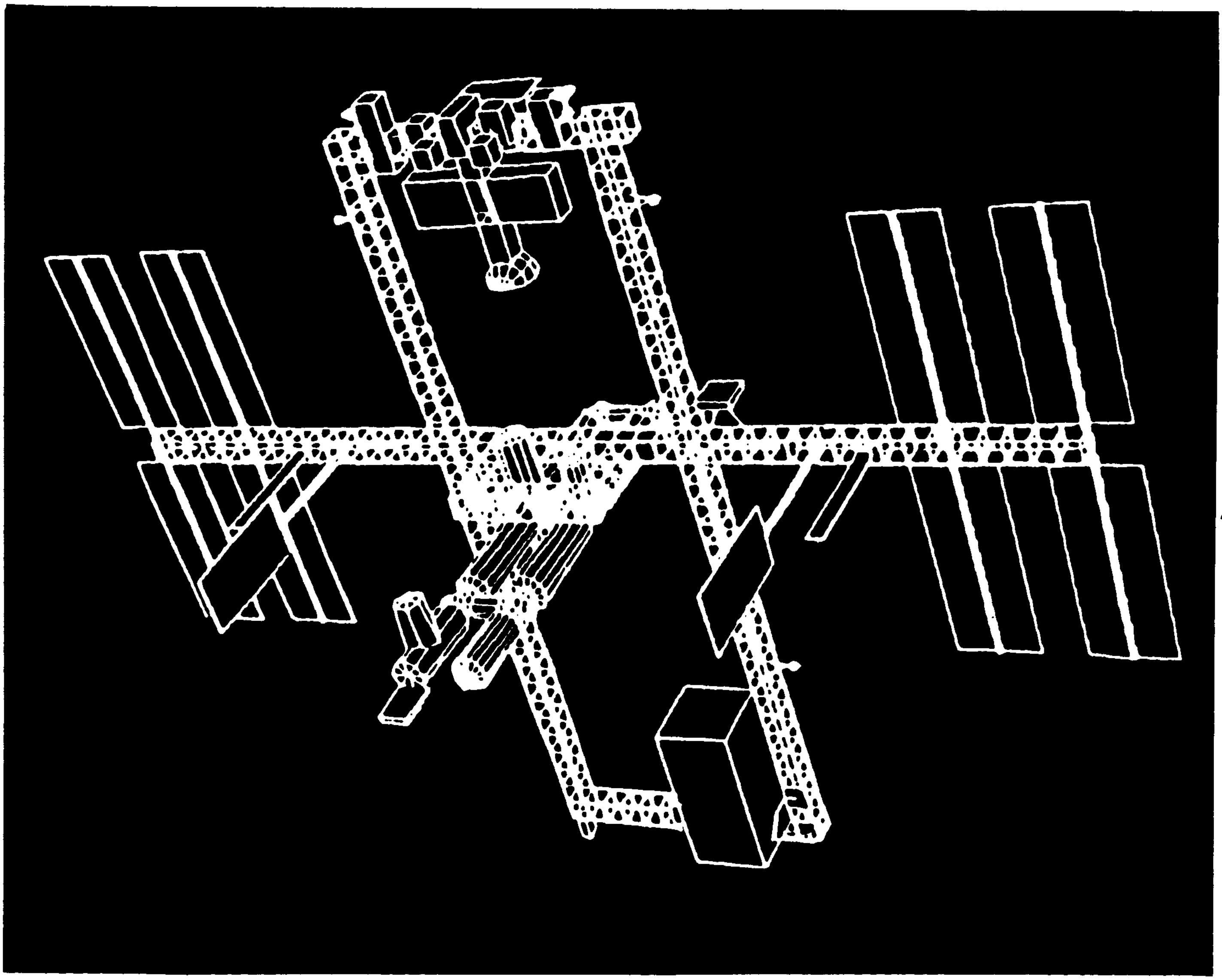
# Space Station Systems

A Bibliography with Indexes

NASA SP-7056(05)
November 1987

(NASA-SP-7056(05)) SPACE STATION SYSTEMS: A BIBLIOGRAPHY WITH INDEXES (NASA) 245 p CSCL 22B
Avail: NTIS HC A11

N88-13382
Unclas
00/18 0114110



NASA SP-7056(05)

# SPACE STATION SYSTEMS

## A BIBLIOGRAPHY WITH INDEXES

## Supplement 5

*Compiled by*
Technical Library Branch
and
*Edited by*
Space Station Office
NASA Langley Research Center
Hampton, Virginia

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system between January 1 and June 30, 1987 in

- *Scientific and Technical Aerospace Reports (STAR)*
- *International Aerospace Abstracts (IAA).*

NASA Scientific and Technical Information Division 1987
National Aeronautics and Space Administration
Washington, DC

NOTE TO AUTHORS OF PROSPECTIVE ENTRIES:

The compilation of this bibliography results from a complete search of the *STAR* and *IAA* files. Many times a report or article is not identified because either the title, abstract, or key words did not contain appropriate words for the search. A number of words are used, but to best insure that your work is included in the bibliography, use the words *Space Station Systems* somewhere in your title or abstract, or include them as a key word.

This supplement is available from the National Technical Information Service (NTIS), Springfield , Virginia 22161 at the price code A11.

# INTRODUCTION

This bibliography is designed to be helpful to the researchers, designers, and managers engaged in the design and development of technology, configurations, and procedures that enhance efficiencies of current and future versions of a Space Station.

This literature survey lists 967 reports, articles and other documents announced between January 1, 1987 and June 30, 1987 in *Scientific and Technical Aerospace Reports (STAR)*, and *International Aerospace Abstracts (IAA)*.

The coverage includes documents that define major systems and subsystems, servicing and support requirements, procedures and operations, and missions for the current and future Space Station. In addition, analytical and experimental techniques and mathematical models required to investigate the different systems/subsystems and conduct trade studies of different configurations, designs, and scenarios are included. A general category completes the list of subjects addressed by this document.

The selected items are grouped into categories as listed in the Table of Contents with notes regarding the scope of each category. These categories were especially selected for this publication and differ from those normally found in *STAR* and *IAA*.

Each entry consists of a standard bibliographic citation accompanied by an abstract, where available, and appears with the original accession numbers from the respective announcement journals.

Under each of the categories, the entries are presented in one of two groups that appear in the following order:

(1) *IAA* entries identified by accession number series A87-10,000 in ascending accession number order;

(2) *STAR* entries identified by accession number series N87-10,000 in ascending accession number order.

After the abstract section there are seven indexes—subject, personal author, corporate source, foreign technology, contract number, report number, and accession number.

A companion continuing bibliography, *"Technology for Large Space Structures,"* is available as NASA SP-7046.

Robert E. Satterthwaite, *Space Station Office*
Sue K. Seward, *Technical Library Branch*

# TABLE OF CONTENTS

# TYPICAL REPORT CITATION AND ABSTRACT

NASA SPONSORED

ON MICROFICHE

| | | |
|---|---|---|
| ACCESSION NUMBER | **N87-11827*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va. | CORPORATE SOURCE |
| TITLE | **DESIGN, CONSTRUCTION AND UTILIZATION OF A SPACE STATION ASSEMBLED FROM 5-METER ERECTABLE STRUTS** | |
| AUTHORS | M. M. MIKULAS, JR. and H. G. BUSH Oct. 1986 40 p | PUBLICATION DATE |
| REPORT NUMBERS | (NASA-TM-89043; NAS 1.15:89043) Avail: NTIS HC A03/MF A01 CSCL 22B | AVAILABILITY SOURCE<br>COSATI CODE |

Presented are the primary characteristics of the 5-meter erectable truss designated for the space station. The relatively large 5-meter truss dimension was chosen to provide a deep beam for high bending stiffness yet provide convenient mounting locations for space shuttle cargo bay size payloads which are 14.5 ft. (4.4 m) in diameter. Truss nodes and quick-attachment erectable joints are described which provide for evolutionary three-dimensional growth and for simple maintenance and repair. A mobile remote manipulator system is described which is provided to assist in station construction and maintenance. A discussion is also presented of the construction of the space station and the associated EVA time. Author

# TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT

NASA SPONSORED

| | | |
|---|---|---|
| ACCESSION NUMBER | **A87-27178*** Virginia Polytechnic Inst. and State Univ., Blacksburg. | |
| TITLE | **SPACE RADIATION EFFECTS ON THE THERMO-MECHANICAL BEHAVIOR OF GRAPHITE-EPOXY COMPOSITES** | |
| AUTHORS | SCOTT M. MILKOVICH, CARL T. HERAKOVICH (Virginia Polytechnic Institute and State University, Blacksburg), and GEORGE F. SYKES (NASA, Langley Research Center, Hampton, VA) Journal of Composite Materials (ISSN 0021-9983), vol. 20, | AUTHOR'S AFFILIATION |
| JOURNAL DATE | Nov. 1986, p. 579-593. refs | |
| CONTRACT NUMBER | (Contract NAG1-343) | JOURNAL TITLE |

This investigation of composite material properties utilized T300/934 graphite-epoxy that was subjected to 1.0 MeV electron radiation for a total dose of 1.0 x 10 to the 10th rads at a rate of 5.0 x 10 to the 7th rads/hour, simulating a worst-case exposure equivalent to 30 years in space. Mechanical testing was performed on 4-ply unidirectional laminates over the temperature range of -250 F (116 K) to +250 F (394 K). In-plane elastic tensile and shear properties as well as strength were obtained. The results show that electron radiation degrades the epoxy matrix and produces products that volatilize at the temperatures considered. These degradation products plasticize the epoxy at elevated temperatures and embrittle it at low temperatures, thereby altering the mechanical properties of the composite. Author

# SPACE STATION SYSTEMS

*A Bibliography (Suppl. 5)*

NOVEMBER 1987

## 01

## SYSTEMS

Includes system requirements for proposed missions, mission models, overall conceptual configuration and arrangement studies; systems analyses for future required technology; and identification and description of technology developments and experiments for the elements of a complete Space Station system.

**A87-10092**
**SPACE VEHICLE DESIGN [CONCEPTION DES VEHICULES SPATIAUX]**
D. MARTY (CNES, Direction des Lanceurs, Evry, France) Paris, Masson, 1986, 666 p. In French. refs

A general overview of the main problems encountered in space vehicle design is presented in order to provide simple methods for the working out of preliminary projects, the comparison of architectures, and the verification of the feasibility of new systems. The discussion on satellites includes such topics as earth escape conditions, theoretical and real movement, orbit plane correction, and thermal control. In[illegible] re discussed with [illegible]ence sphere and orbit transfers. The performance, separation and jettisoning, and aerodynamics of conventional space launchers are then considered. Problems relating to reusable launch vehicles, ballistic missiles, the reentry body, and the Space Station are also discussed. Finally, a general discussion of the avionics, propulsion, and structural technology common to all space vehicles is presented, including instrumentation, energy sources, launcher guidance and attitude control, rocket engine thrust, and combustion. Also considered are propellants, engine characteristics, advanced propulsive systems, and structural materials and manufacturing. R.R.

**A87-11013**
**PARAMETRIC STUDY OF STABLE OPTICAL REFERENCES FOR LARGE FLEXIBLE STRUCTURES IN SPACE**
M. J. CLAYTON and A. L. WERTHEIMER (Eastman Kodak Co., Rochester, NY) IN: Large optics technology; Proceedings of the Meeting, San Diego, CA, August 19-21, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 149-157.

Several concepts for keeping track of small relative angular motions between a reference point and a remote platform, when the two are located at separate points on a flexible structure, are discussed. The goal is to accurately transfer knowledge of the orientation of the remote platform relative to the reference point. First-order equations and order-of-magnitude calculations are presented for image centroiding and interference fringe projection approaches for space station applications. Author

**A87-11359#**
**SPACE CONSTRUCTIBLE RADIATOR ON-ORBIT ASSEMBLY**
P. J. OTTERSTEDT, J. HUSSEY, and J. P. ALARIO (Grumman Aerospace Corp., Bethpage, NY) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 23, July-Aug. 1986, p. 397-400. Previously cited in issue 17, p. 2472, Accession no. A85-37667.

**A87-13434*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.
**TRAJECTORY SHAPING RENDEZVOUS GUIDANCE**
A. R. KLUMPP (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: 1986 American Control Conference, 5th, Seattle, WA, June 18-20, 1986, Proceedings. Volume 3 . New York, Institute of Electrical and Electronics Engineers, 1986, p. 1545-1550. NASA-supported research.

The Space Station will bring a great increase in rendezvous traffic. Formerly, rendezvous has been expensive in terms of time and crew involvement. Multiple trajectory adjustments on separate orbits have been required to meet safety, lighting, and geometry requirements. This paper describes a new guidance technique in which the approach trajectory is shaped by a sequence of velocity increments in order to satisfy multiple constraints within a single orbit. The approach phase is planned before the mission, leaving a group of free parameters that are optimized by onboard guidance. Fuel penalties are typically a few percent, compared to unshaped Hohmann transfers, and total fuel costs can be less than those of more time-consuming ways of meeting the same requirements. Author

**A87-15382**
**SPACE STATION - AN ERA OF NEW CAPABILITIES AND NEW TECHNOLOGIES**
D. C. WENSLEY (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: Space Station beyond IOC; Proceedings of the Thirty-second Annual International Conference, Los Angeles, CA, November 6, 7, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 65-70.
(AAS PAPER 85-462)

The technologies and configurations chosen for the Space Station IOC will determine the directions of developmental efforts for the foreseeable future. Computer graphics images are provided of the new reference configuration as of November 1985, illustrating the figure-8 pattern to be formed by the basic pressurized modules and interconnects. Development of a component commonality and a knowledge-based system (for mission operations) is considered essential for rapid growth beyond IOC. M.S.K.

**A87-15822*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**DEFINITION STATUS OF THE U.S. SPACE STATION SYSTEM**
M. K. CRAIG (NASA, Johnson Space Center, Houston, TX) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 7 p.
(IAF PAPER 86-32)

The configuration, design, and capabilities of the Space Station are briefly reviewed. In particular, attention is given to the truss structure, photovoltaic and solar dynamic power generation systems, pressurized habitation and laboratory modules, and provisions for extravehicular activity. The discussion covers the Space Station assembly sequence, and the main elements of the power, communication, environmental, and life support systems of the Space Station. V.L.

**A87-16928*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**NEW SHAPE IN THE SKY**
J. W. AARON (NASA, Johnson Space Center, Houston, TX) Aerospace America (ISSN 0740-722X), vol. 24, Sept. 1986, p. 30, 31.

The 'dual keel' design currently under consideration for NASA's Space Station program is of rectangular configuration to yield greater space along the truss structure for the attachment of payloads, by comparison with a previously considered single-keel truss design. The placing of the pressurized modules much nearer the center of gravity of this station configuration allows accelerations that are closer to 1 micro-g than the earlier alternative. The U.S. Servicing Facility and Telerobotic System, and the Canadian Mobile Servicing Center, will be incorporated in order to meet a large variety of Space Station servicing requirements. O.C.

**A87-20351**
**SPACE STATIONS AND PLATFORMS**
GORDON R. WOODCOCK Malabar, FL, Orbit Book Co., 1986, 229 p.

The book offers a broad systems view of the engineering of space stations and platforms on a project scale. Topics include space station operations, orbital mechanics, space environments, and subsystems for space stations and platforms. Consideration is also given to crew systems and crew accommodations, mass properties analysis, configuration and design integration, and cost and cost estimating. K.K.

**A87-21504#**
**INTEGRATED ECLSS/PROPULSION SYSTEM FOR SPACE STATION**
J. GREG MCALLISTER (Martin Marietta Corp., Denver, CO) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 22nd, Huntsville, AL, June 16-18, 1986. 11 p.
(AIAA PAPER 86-1406)

It is proposed that the excess hydrogen released by the Space Station's ECLSS could be utilized by an O2/H2 based propulsion system. This would lead to improved propulsion performance as well as the elimination of a waste hydrogen system. The total component count could also be reduced with an integrated system owing to the reduction in ECLSS and propulsion system complexity and the sharing of functions between the two systems. It is shown that the preliminary program cost savings will more than offset any additional development costs. K.K.

**A87-22553*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**SPACE STATION OVERVIEW**
CARMINE E. DE SANCTIS, C. C. PRIEST, and W. V. WOOD (NASA, Marshall Space Flight Center, Huntsville, AL) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 12 p. refs
(AIAA PAPER 87-0315)

This paper presents an overview of the Space Station, including program guidelines, international involvement, current baseline configuration, and utilization for science and application missions. Space Station configuration and capabilities, plus methods of utilizing the Space Station for scientific and engineering investigations, are described. The Space Station is being designed as a multipurpose facility to support a number of functions, such as a laboratory in space, a transportation node, an assembly facility, a staging base, etc. The description includes the baseline configuration, location of the pressurized modules, servicing and assembly facilities, and the work package structure for Space Station management. The Space Station will accommodate a wide variety of user requirements in laboratory modules and as attached payloads. To show the utility of the Space Station, a variety of science and application missions currently being studied for NASA at the Marshall Space Flight Center are discussed. Author

**A87-25457*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**SPACE STATION REFERENCE CONFIGURATION UPDATE**
TOM F. BONNER, JR. (NASA, Johnson Space Center, Houston, TX) IN: Space Station: Gateway to space manufacturing; Proceedings of the Conference, Orlando, FL, Nov. 7, 8, 1985 . Arlington, VA, Pasha Publications, 1985, 40 p.

The reference configuration of the NASA Space Station as of November 1985 is presented in a series of diagrams, drawings, graphs, and tables. The configurations for components to be contributed by ESA, Canada, and Japan are included. Brief captions are provided, along with answers to questions raised at the conference. T.K.

**A87-25976**
**AEROSPACE APPLICATIONS CONFERENCE, STEAMBOAT SPRINGS, CO, FEB. 1-8, 1986, DIGEST**
Conference sponsored by IEEE. New York, Institute of Electrical and Electronics Engineers, Inc., 1986, 359 p. For individual items see A87-25977 to A87-26000.

The present conference considers topics concerning the projected NASA Space Station's systems, digital signal and data processing applications, and space science and microwave applications. Attention is given to Space Station video and audio subsystems design, clock error, jitter, phase error and differential time-of-arrival in satellite communications, automation and robotics in space applications, target insertion into synthetic background scenes, and a novel scheme for the computation of the discrete Fourier transform on a systolic processor. Also discussed are a novel signal parameter measurement system employing digital signal processing, EEPROMS for spacecraft applications, a unique concurrent processor architecture for high speed simulation of dynamic systems, a dual polarization flat plate antenna, Fresnel diffraction, and ultralinear TWTs for high efficiency satellite communications. O.C.

**A87-25978**
**ARCHITECTURE AND DESIGN PROCESS FOR COMPLEX SYSTEMS: SPACE STATION - A CASE STUDY**
RICHARD T. LUKE (Hughes Aircraft Co., Space and Communications Group, El Segundo, CA) IN: Aerospace Applications Conference, Steamboat Springs, CO, Feb. 1-8, 1986, Digest . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, 16 p.

The system architecture and design (A&D) process involves the identification of a set of mission objectives and the definition of detailed block diagrams for each element of a system that can accomplish said objectives. Attention is presently given to the distinct phases of A&D, drawing upon examples from recent NASA Space Station activities in general and the Station's communications system in particular; a specific segment of the communications system is presented to illustrate the application of the complete A&D process. It is noted that the risk associated with early freezing of baseline designs can be minimized by involving representatives from subsequent design phases in preceding ones. O.C.

**A87-25979**
**SPACE STATION VIDEO SUBSYSTEM DESIGN**
JEFFREY W. CROSBY and RUSSELL A. GASPARI (Hughes Aircraft Co., Los Angeles, CA) IN: Aerospace Applications Conference, Steamboat Springs, CO, Feb. 1-8, 1986, Digest . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, 11 p.

An account is given of the design process employed in the Phase B trade study definition of the NASA Space Station's video subsystem, whose requirements were initially defined by a NASA request for proposals. The video subsystem furnishes transmission, reception, digitization, distribution, and switching of all Space Station video, including commercial color TV for crew entertainment and training, and CCTV signals for various spacecraft operations. Duplex transmission of standard TV must be provided between

the Space Station and ground, as well as freeze-frame, compression, and slow scan TV services. O.C.

**A87-25980**
**SPACE STATION AUDIO SUBSYSTEM DESIGN - A CASE STUDY**
JEFFREY W. CROSBY and RUSSELL A. GASPARI (Hughes Aircraft Co., Los Angeles, CA) IN: Aerospace Applications Conference, Steamboat Springs, CO, Feb. 1-8, 1986, Digest . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, 11 p.

Attention is given to the character and results of a Phase B system design case study undertaken for the NASA Space Station's audio subsystem. The baseline design presented employs an audio distribution bus technique that complements the self-contained character of the Space Station's habitable modules and facilitates expansion in the course of Space Station on-orbit configuration growth and evolution. The absence of hardwired frequency channels allows this implementation scheme to assign channels as required. The treatment of the wireless as simply another Audio Communication Station allows astronaut location and/or health status telemetry to be monitored throughout the Space Station without adding a separate network. O.C.

**A87-29466#**
**UTILIZATION, TESTING AND MAINTENANCE OF MULTIMISSION HARDWARE**
G. K. JANES and R. L. RADCLIFFE (Martin Marietta Corp., Denver, CO) IN: Aerospace Testing Seminar, 9th, Los Angeles, CA, Oct. 15-17, 1985, Proceedings . Mount Prospect, IL, Institute of Environmental Sciences, 1986, p. 206-210.

The preflight testing, operation, and postflight inspection of the Manned Maneuvering Unit (MMU)/Flight Support Station (FSS) [illegible] MMU/FSS, and the functions of the MMU Depot are examined. Examples revealing the preflight and postflight testing and inspection of the MMU/FSS for various space missions are presented. Diagrams of the MMU and FSS are provided. I.F.

**N87-10170*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**A SPACE STATION STRUCTURES AND ASSEMBLY VERIFICATION EXPERIMENT, SAVE**
R. A. RUSSELL, J. P. RANEY, and L. J. DERYDER Aug. 1986 376 p
(NASA-TM-89004; NAS 1.15:89004) Avail: NTIS HC A17/MF A01 CSCL 22B

The Space Station structure has been baselined to be a 5 M (16.4 ft) erectable truss. This structure will provide the overall framework to attach laboratory modules and other systems, subsystems and utilities. The assembly of this structure represents a formidable EVA challenge. To validate this capability the Space Station Structures/Dynamics Technical Integration Panel (TIP) met to develop the necessary data for an integrated STS structures flight experiment. As a result of this meeting, the Langley Research Center initiated a joint Langley/Boeing Aerospace Company study which supported the structures/dynamics TIP in developing the preliminary definition and design of a 5 M erectable space station truss and the resources required for a proposed flight experiment. The purpose of the study was to: (1) devise methods of truss assembly by astronauts; (2) define a specific test matrix for dynamic characterization; (3) identify instrumentation and data system requirements; (4) determine the power, propulsion and control requirements for the truss on-orbit for 3 years; (5) study the packaging of the experiment in the orbiter cargo bay; (6) prepare a preliminary cost estimate and schedule for the experiment; and (7) provide a list of potential follow-on experiments using the structure as a free flyer. The results of this three month study are presented. M.G.

**N87-11827*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**DESIGN, CONSTRUCTION AND UTILIZATION OF A SPACE STATION ASSEMBLED FROM 5-METER ERECTABLE STRUTS**
M. M. MIKULAS, JR. and H. G. BUSH Oct. 1986 40 p
(NASA-TM-89043; NAS 1.15:89043) Avail: NTIS HC A03/MF A01 CSCL 22B

Presented are the primary characteristics of the 5-meter erectable truss designated for the space station. The relatively large 5-meter truss dimension was chosen to provide a deep beam for high bending stiffness yet provide convenient mounting locations for space shuttle cargo bay size payloads which are 14.5 ft. (4.4 m) in diameter. Truss nodes and quick-attachment erectable joints are described which provide for evolutionary three-dimensional growth and for simple maintenance and repair. A mobile remote manipulator system is described which is provided to assist in station construction and maintenance. A discussion is also presented of the construction of the space station and the associated EVA time. Author

**N87-12592*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**VIEWPORT CONCEPT FOR SPACE STATION MODULES**
F. DOUGLAS, III Aug. 1986 28 p
(NASA-TM-86559; NAS 1.15:86559) Avail: NTIS HC A03/MF A01 CSCL 22B

The generic design of a 20-in. diameter viewport for the space station modules is discussed. It should possess the capabilities of meteoroid/debris protection (with no metallic cover), redundancies in its meteoroid/debris protection, and pressure sealing systems. In addition, it should provide ease of change out for maintenance or repair. The design does not take into account the bumper-shield effect of the outermost panes in the meteoroid/debris analysis. Author

**N87-16025*#** National Aeronautics and Space Administration.
**THE 15 METER HOOP-COLUMN ANTENNA DYNAMICS: TEST AND ANALYSIS**
W. KEITH BELVIN and HAROLD H. EDIGHOFFER (Edighoffer, Inc., Newport News, Va.) *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 167-185 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 20N

A 15 meter model of the hoop-column antenna concept has been vibration tested for model characterization and analytical model verification. Linear finite element analysis predicted the global vibration frequencies accurately. Good agreement between analysis and test data was obtained only after the analytical model was refined using static test data. As structures become more flexible, structural properties determined from static data become more accurate and should be used to update analytical models. Global vibration modes are not significantly affected by the surface mesh which permits simplified analytical models to be used for prediction of global behavior. These reduced models are believed sufficient for preliminary design and controls simulations where only global behavior is desired. The mesh modes were highly damped due to the knit mesh used for the reflector surface. These modes were also highly coupled and very difficult to measure in the laboratory. The inability to fully characterize the antenna mesh modes in the laboratory indicates robust methods for active surface vibration suppression will be needed. Fortunately, the surface mesh exhibits high passive damping which should be beneficial to active control systems. Author

**N87-16027*#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.
**SENSOR TECHNOLOGY FOR ADVANCED SPACE MISSIONS**
N. M. NERHEIM and R. P. DEPAULA *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 207-219 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 14B

The capability and applications of two sensors, Spatial, High-Accuracy, Position-Encoding Sensor (SHAPES) and Fiber

Optics Rotation Sensor (FORS), for advanced missions are discussed. The multiple target, 3-D position sensing capability of SHAPES meets a critical technology need for many developing applications. A major milestone of the SHAPES task was completed on schedule on May 30, 1986, by demonstrating simultaneous ranging to eight moving targets at a rate of 10 measurements per second. The range resolution to static target was shown to be 25 microns. SHAPES scheduled technology readiness will support the sensor needs of a number of early users. The next phase in the development of SHAPES is to incorporate an angular measurement CCD to provide the full 3-dimensional sensing. A flight unit design and fabrication can be complete by FY89. FORS, with its significant improvement over present technology in lifetime, performance, weight, power, and recurrent cost, will be an important technology for future space systems. Technology readiness will be demonstrated with a FORS brassboard with fully integrated IO chips by FY88. The unique capability of miniature remote sensing heads, connected to a central system, will open up new areas in control and stability of large space structures. This application requires additional study. Author

**N87-16927#** Contraves Corp., Zurich (Switzerland). Space Dept.
**DEVELOPMENT OF A 2.8 M OFFSET ANTENNA REFLECTOR USING INFLATABLE, SPACE-RIGIDIZED STRUCTURES TECHNOLOGY**
M. C. BERNASCONI *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 31-37 Aug. 1986
Avail: NTIS HC A12/MF A01
Results of the mechanical tests of an offset reflector structure, based on the technology of chemically-rigidized membranes are presented. Folding, stowage, and deployment tests confirm the high packaging efficiency, as well as the controllability of the inflation process. Geometric measurements at different manufacturing stages were used to assess the quality of the surface; the typical surface deviation obtained is 0.9 mm rms. Folding and cure processes have a negligible impact on reflector quality. The packaging and deployment procedures were verified by a depolyment test in vacuum. ESA

**N87-17029** California Univ., Los Angeles.
**A MODIFIED LOOP TRANSFER RECOVERY APPROACH FOR ROBUST CONTROL OF FLEXIBLE STRUCTURES Ph.D. Thesis**
PAUL ANDREW BLELLOCH 1986 214 p
Avail: Univ. Microfilms Order No. DA8621022
A procedure is developed for dealing with performance and robustness issues in the design of multi-input multi-output compensators for lightly damped flexible structures. The procedure is based upon representing errors in the plant design model as structured uncertainties, and applying a modified version of the Loop Transfer Recovery (LTR) design method. Real parameter errors such as frequency errors, damping errors or modal displacement errors can be treated. The modified method may be implemented in either of two slightly different forms, both of which permit a controlled tradeoff between performance and robustness. The first approach is the main focus. It involves adjusting the cost function in the regulator problem and the process noise model in the estimator problem in a particular manner which reflects the assumed structure of the modeling errors. Numerical examples dealing with the control of a large flexible space antenna with uncertain frequencies demonstrate that this approach represents a considerable improvement over standard LTR methods. Convenient design parameters can be varied until a satisfactory compromise is achieved between performance and robustness. The second approach is a variation on the first in that it uses a similar procedure for adjusting the cost function in the (full-state feedback) regulator problem. Instead of implementing the controller with an estimator, an algebraic procedure is used to achieve loop recovery with a compensator whose poles can be placed at arbitrary locations. Dissert. Abstr.

**N87-17820*** National Aeronautics and Space Administration, Washington, D.C.
**SPACE STATION SYSTEMS: A CONTINUING BIBLIOGRAPHY WITH INDEXES (SUPPLEMENT 3)**
Jan. 1987 205 p
(NASA-SP-7056(03); NAS 1.21:7056(03)) Avail: NTIS HC A10 CSCL 22A
This bibliography lists 780 reports, articles and other documents introduced into the NASA scientific and technical information system between January 1, 1986 and June 30, 1986. Its purpose is to provide helpful information to the researcher, manager, and designer in technology development and mission design according to system, interactive analysis and design, structural and thermal analysis and design, structural concepts and control systems, electronics, advanced materials, assembly concepts, propulsion, and solar power satellite system. The coverage includes documents that define major systems and subsystems, servicing and support requirements, procedures and operations, and missions for the current and future space station. Author

**N87-17840*#** Boeing Aerospace Co., Huntsville, Ala.
**SPACE STATION FINAL STUDY REPORT. VOLUME 1: EXECUTIVE SUMMARY**
18 Jan. 1987 21 p
(Contract NAS8-36526)
(NASA-CR-179021-VOL-1; NAS 1.26:179021-VOL-1; D483-50115-1; DR-15-DATA-PKG-WP-01; FSCM-81205) Avail: NTIS HC A02/MF A01 CSCL 22B
Volume 1 of the Final Study Report provides an Executive Summary of the Phase B study effort conducted under contract NAS8-36526. Space station Phase B implementation resulted in the timely establishment of preliminary design tasks, including trades and analyses. A comprehensive summary of project activities in conducting this study effort is included. Author

**N87-17841*#** Martin Marietta Aerospace, Denver, Colo. Systems Analysis and Support.
**SPACE STATION DEFINITION AND PRELIMINARY DESIGN, WP-01. VOLUME 2: RESULTS Final Study Report**
J. A. LENDA 16 Jan. 1987 348 p
(Contract NAS8-36525)
(NASA-CR-179024; NAS 1.26:179024; SSP-MMC-00055-VOL-2; DR-15-VOL-2) Avail: NTIS HC A15/MF A01 CSCL 22B
The basis for the studies and analyses which led to the results and conclusions documented and summarized, was the Engineering Master Schedule (EMS) generated by NASA and used as the controlling set of milestones and associated activities required to produce in a timely manner those products needed by all program participants in the establishment of an approved program baseline. The EMS consisted of twenty themes grouped into categories covering requirements, configurations, and strategies. A number of studies and analyses that were coordinated with the MSFC program and technical personnel as being needed to provide the requisite back-up material to satify the EMS were identified. These studies and analyses provided the data sufficient to support the conclusions and recommendations given to the MSFC in response to their EMS activity and to support the system level and conceptual design level approaches developed and reflected in the detailed sections of this document. B.G.

**N87-17842*#** Martin Marietta Corp., Denver, Colo. Systems Analysis and Support.
**SPACE STATION DEFINITION AND PRELIMINARY DESIGN, WP-01. VOLUME 1: EXECUTIVE SUMMARY Final Study Report**
J. A. LENDA 16 Jan. 1987 94 p
(Contract NAS8-36525)
(NASA-CR-179023; NAS 1.26:179023; SSP-MMC-00055-VOL-1; DR-15-VOL-1) Avail: NTIS HC A05/MF A01 CSCL 22B
System activities are summarized and an overview of the system level engineering tasks performed are provided. Areas discussed include requirements, system test and verification, the advanced development plan, customer accommodations, software, growth,

productivity, operations, product assurance and metrication. The hardware element study results are summarized. Overviews of recommended configurations are provided for the core module, the USL, the logistics elements, the propulsion subsystems, reboost, vehicle accommodations, and the smart front end. A brief overview is provided for costing activities. B.G.

**N87-17843*#** Boeing Aerospace Co., Huntsville, Ala. Space Station Program.
**SPACE STATION SYSTEM ENGINEERING AND INTEGRATION (SE AND I). VOLUME 2: STUDY RESULTS Final Study Report**
18 Jan. 1987 488 p
(Contract NAS8-36526)
(NASA-CR-179022; NAS 1.26:179022; FSCM-81205-VOL-2; D483-50115-2-VOL-2) Avail: NTIS HC A21/MF A01 CSCL 22B

A summary of significant study results that are products of the Phase B conceptual design task are contained. Major elements are addressed. Study results applicable to each major element or area of design are summarized and included where appropriate. Areas addressed include: system engineering and integration; customer accommodations; test and program verification; product assurance; conceptual design; operations and planning; technical and management information system (TMIS); and advanced development. B.G.

## 02

## MODELS, ANALYTICAL DESIGN TECHNIQUES, AND ENVIRONMENTAL DATA

Includes descriptions of computerized interactive systems design and development techniques, computer codes, internal and external environmental models and data.

**A87-14084*#** Systems Science and Software, La Jolla, Calif.
**THREE DIMENSIONAL SIMULATION OF THE OPERATION OF A HOLLOW CATHODE ELECTRON EMITTER ON THE SHUTTLE ORBITER**
V. A. DAVIS, I. KATZ, M. J. MANDELL, and D. E. PARKS (Systems Science and Software, La Jolla, CA) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 16 p. refs
(Contract NAS3-23881)

Several researchers have suggested using hollow cathodes as plasma contactors for electrodynamic tethers, particularly to prevent the shuttle orbiter from charging to large negative potentials. Previous studies have shown that fluid models with anomalous scattering can describe the electron transport in hollow cathode generated plasmas. An improved theory of the hollow cathode plasmas is developed and computational results using the theory are compared with laboratory experiment. Numerical predictions for a hollow cathode plasma source of the type considered for use on the shuttle are presented as are three-dimensional NASCAP/LEO calculations of the emitted ion trajectories and the resulting potentials in the vicinity of the orbiter. The computer calculations show that the hollow cathode plasma source makes vastly superior contact with the ionospheric plasma compared with either an electron gun or passive ion collection by the orbiter. Author

**A87-15812*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**THE USE OF COMPUTER GRAPHIC SIMULATION IN THE DEVELOPMENT OF ROBOTIC SYSTEMS**
K. FERNANDEZ (NASA, Marshall Space Flight Center, Huntsville, AL) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. refs
(IAF PAPER 86-16)

This paper describes the use of computer graphic simulation techniques to resolve critical design and operational issues for robotic systems. Use of this technology will result in greatly improved systems and reduced development costs. The major design issues in developing effective robotic systems are discussed and the use of ROBOSIM, a NASA developed simulation tool, to address these issues is presented. Three representative simulation case studies are reviewed: off-line programming of the robotic welding development cell for the Space Shuttle Main Engine (SSME); the integration of a sensor to control the robot used for removing the Thermal Protection System (TPS) from the Solid Rocket Booster (SRB); and the development of a teleoperator/robot mechanism for the Orbital Maneuvering Vehicle (OMV). Author

**A87-16105#**
**MODELING AND SIMULATION OF LARGE SCALE SPACE SYSTEMS STRATEGIC PLANNING IMPLICATIONS**
S. NOZETTE, H. DAVIS (Large Scale Programs Institute, Austin, TX), and C. BILBY (Texas, University, Austin) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 6 p. refs
(IAF PAPER 86-453)

**A87-16141#**
**REDUCED MODELING AND ANALYSIS OF LARGE REPETITIVE SPACE STRUCTURES VIA CONTINUUM/DISCRETE CONCEPTS**
K. C. SAW (West Virginia University, Morgantown) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 12 p. refs
(IAF PAPER ST-86-08)

A reduced modeling/analysis approach applicable for repetitive lattice configuration is described with emphasis on tetrahedral-type space structures. Using scaling transformations and constitutive properties derived via the concept of 'equivalent continuum', the actual models are transformed to significantly reduced discrete configurations. Therein, the approach seeks to model/analyze the much simpler and reduced configurations, wherein, transformations and extrapolation/interpolation procedures are utilized to relate back the response to that of significantly complex actual [illegible] demonstrated via comparisons with detailed analysis of the actual models. Results obtained are in good agreement and the approach offers potential for further extension. The basic concepts can be extended to general repetitive lattice structures as well. Author

**A87-17760#**
**MODELING AND SIMULATION OF SPACECRAFT SOLAR ARRAY DEPLOYMENT**
B. WIE, N. FURUMOTO, A. K. BANERJEE, and P. M. BARBA (Ford Aerospace and Communications Corp., Palo Alto, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 9, Sept.-Oct. 1986, p. 593-598. Previously cited in issue 23, p. 3428, Accession no. A86-47923. refs

**A87-18106**
**ESTIMATING PERFORMANCE CHARACTERISTICS OF RECHARGEABLE SILVER-ZINC (AGZN) BATTERIES FOR SPACE APPLICATIONS USING MULTIPLE REGRESSION ANALYSIS**
R. R. DAVIS, JR. (Martin Marietta Corp., Denver, CO) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1612-1616.

The use of a statistical model to estimate the performance characteristics of rechargeable AgZn batteries is examined. An AgZn vented cell is subjected to 15 cycle-continuous-cycle tests and 2 cycles of the periodic cycling test. The relationship between battery capacity and number of cycles and days since activation is analyzed; the statistical model is developed using multiple regression analysis. It is noted that multiple regression analysis is a useful technique for the design of battery and power systems. I.F.

**A87-18114**
**1986 LECEC STABILITY AND TRANSIENT MODELING OF A LARGE SPACECRAFT POWER SYSTEM**
J. CHEN and M. GLASS (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1672-1676.

As space power systems grow and computer aided engineering workstations mature, computer modeling becomes a critical design step. This paper outlines the modeling process of a multi kw spacecraft power system comprised of eight solar powered converter/battery channels, three control loops including the peak power tracker, and a common output bus. The computer models predicted small signal stability margins, bus impedances, and fault induced voltage transients. Author

**A87-19898**
**FATIGUE SIMULATION TESTING OF SOLAR CELL INTERCONNECTORS**
R. E. NEFF, H. E. POLLARD (Ford Aerospace and Communications Corp., Palo Alto, CA), and W. R. BARON IN: Photovoltaic Specialists Conference, 18th, Las Vegas, NV, October 21-25, 1985, Conference Record . New York, Institute of Electrical and Electronics Engineers, Inc., 1985, p. 629-633. refs

Lifetimes of 10 years or more for geostationary earth orbits (GEO) and 10 to 20 years for low earth orbits (LEO) e.g. Space Station, require solar cell interconnectors to withstand up to 880 orbital temperature cycles in GEO and not less than 60 thousand orbital temperature cycles in LEO. Similarly, terrestrial applications also require extended solar array lifetimes of 7,300 temperature cycles (20 yrs) or more to minimize life-cycle costs. This paper describes the test equipment, test results and analysis performed for mechanical simulation of the interconnect dimensional changes which take place due to operational temperature cycles. Typical solar array substrate materials are examined together with the effects of interconnector materials and design dimensional changes upon predicted cycling lifetimes. Author

**A87-21993**
**ANALYSIS OF THE ION SPOT PHENOMENON ON BEAM-CHARGED DIELECTRICS**
GORDON MCKEIL and K. G. BALMAIN (Toronto, University, Canada) (IEEE, DNA, Sandia National Laboratories, and NASA, 1986 Annual Conference on Nuclear and Space Radiation Effects, 23rd, Providence, RI, July 21-23, 1986) IEEE Transactions on Nuclear Science (ISSN 0018-9499), vol. NS-33, Dec. 1986, pt. 1, p. 1396-1401. refs
(Contract AF-AFOSR-84-0342; NSERC-A-4140)

Computer simulation of particle trajectories in two dimensions using a simple static accumulated charge model reveals the mechanism for the focussing of ions into a central, sharply defined 'spot', duplicating the luminescent spot which did not arc-discharge observed during laboratory exposure of polymer film to monoenergetic electrons and low energy ions. A model which follows the time evolution of such charging situations is developed and initial results are presented. Author

**A87-22814**
**EFFICIENT OPTIMIZATION OF SPACE TRUSSES**
HOJJAT ADELI (Ohio State University, Columbus) and OSAMA KAMAL Computers and Structures (ISSN 0045-7949), vol. 24, no. 3, 1986, p. 501-511. refs

An efficient and robust algorithm is developed for minimum weight design of space trusses with fixed geometry employing the general geometric programming (GGP) technique. The nonlinear programming (NLP) problem is formulated based on the virtual work method of structural analysis. The objective function is linear, subjected to linear size and stress constraints and nonlinear displacement constraints. Based on an arbitrary starting point, the signomials are condensed into posynomials and subsequently into monomials. Next, the monomials are linearized through logarithmic transformation. The resulting linear programming (LP) problem is solved iteratively using a dual simplex algorithm until the optimal feasible solution eventually coincides with a local optimum of the approximated problem. This solution point is then used to formulate a new approximated problem and the same procedure is automatically repeated until the solution of the original problem is found. Five examples are presented to illustrate the application of the algorithm presented in this paper. Author

**A87-24919*#** Physical Sciences, Inc., Andover, Mass.
**ENERGETIC OXYGEN ATOM MATERIAL DEGRADATION STUDIES**
GEORGE E. CALEDONIA and ROBERT H. KRECH (Physical Sciences, Inc., Andover, MA) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 12 p. refs
(Contract NAS7-938)
(AIAA PAPER 87-0105)

As part of a study designed to test potential Shuttle surface materials for the extents of degradation and mass loss expected to be suffered in space from the velocity impacts of ambient oxygen atoms, a novel technique was developed for generation of a high flux of energetic oxygen atoms. The generation technique involves laser-induced breakdown of molecular oxygen followed by a rapid expansion of energetic oxygen atoms. The high-velocity streams developed in an evacuated hypersonic nozzle have average O-atom velocities of about 5 to 13 km/s, with an estimated total production of 10 to the 18th atoms per pulse over pulse durations of several microseconds. Results on preliminary material degradation tests conducted with this test facility have been reported by Caledonia et al. (1987). Diagrams of the experimental setup are included. I.S.

**A87-27936*#** Physical Sciences, Inc., Andover, Mass.
**A HIGH FLUX SOURCE OF ENERGETIC OXYGEN ATOMS FOR MATERIAL DEGRADATION STUDIES**
GEORGE E. CALEDONIA, ROBERT H. KRECH, and BYRON D. GREEN (Physical Sciences, Inc., Andover, MA) (Shuttle Environment and Operations II Conference, Houston, TX, Nov. 13-15, 1985, Technical Papers, p. 153-159) AIAA Journal (ISSN 0001-1452), vol. 25, Jan. 1987, p. 59-63. Previously cited in issue 03, p. 267, Accession no. A86-14399. refs
(Contract NAS7-938)

**A87-28569**
**COMPUTATION OF TOTAL RESPONSE MODE SHAPES USING TUNED FREQUENCY RESPONSE FUNCTIONS**
RALPH BRILLHART and DAVID L. HUNT (SDRC, Inc., San Diego, CA) IN: International Modal Analysis Conference, 4th, Los Angeles, CA, Feb. 3-6, 1986, Proceedings. Volume 2 . Schenectady, NY, Union College, 1986, p. 1228-1236. refs

A new approach called Move Response on Trace allows rapid computation of mode frequencies and shapes immediately following data acquisition. The technique is applicable to multiple-input modal tests in which frequency response functions are obtained. When this technique was applied to an aerospace structure, the results compared well with the polyreference approach, yielding results in considerably less time with less user interaction. Author

**N87-10138** Instituto de Pesquisas Espaciais, Sao Jose dos Campos (Brazil).
**PARAMETER OPTIMIZATION AND ATTITUDE STABILIZATION OF A FLEXIBLE SPACECRAFT**
D. C. CEBALLOS *In* CNES Proceedings of an International Conference on Space Dynamics for Geostationary Satellites p 405-412 1986
Avail: CEPADUES-Editions, 111 rue Nicolas-Vauquelin, 31100 Toulouse, France

The synthesis and analysis of a control law for a flexible spacecraft are described. The control law is considered a simple proportional, integral, and derivative law together with a second order structural filter. Parameter optimization is applied for finding the controller parameters, to optimize behavior when applied to the high order model. Frequency and Laplace domain analysis

which indicate the satisfactory behavior of the proposed controller are shown. ESA

**N87-10720*#** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
**PROCEEDINGS OF THE 5TH ANNUAL USERS' CONFERENCE**
M. SZCZUR, ed. and E. HARRIS, ed. 1985 400 p Conference held at Greenbelt, Md., 4-6 Jun. 1985
(NASA-CP-2399; NAS 1.55:2399) Avail: NTIS HC A17/MF A01 CSCL 09B

The Transportable Applications Executive (TAE) was conceived in 1979. It was proposed to be a general purpose software executive that could be applied in various systems. The success of this concept and of TAE was demonstrated. Topics included: TAE current status; TAE development; TAE applications; and UNIX emphasis. B.G.

**N87-10894#** Engineering System International, Rungis (France).
**EQUIVALENT CONTINUUM ANALYSES OF LARGE SPACE TRUSSES**
E. HAUG, P. DOWLATYARI, and J. DUBOIS *In* ESA Proceedings of an International Conference on Spacecraft Structures p 57-65 Apr. 1986
(Contract ESTEC-5209/82-NL-PB(SC))
Avail: NTIS HC A19/MF A01

The techniques of discrete field methods, conventional equivalent continua, and micropolar equivalent continua are introduced, and their usefulness for the calculation of large space structures and their ease of numerical implementation are assessed. An example of a large space truss was run on the computer, using the full model, and several equivalent continuum finite element models. The full and equivalent continuum models [illegible] with mechanical load cases characteristic of orbital transfer conditions and with thermal gradients which might arise in operating conditions. Dynamic behavior is studied by extracting vibration frequencies and mode shapes. Results suggest that it is better to channel development efforts into an integrated sandwich finite element, uniting anisotropic membrane skins and an anisotropic brick or thick shell core into one element. This type of element is likely to be useful as an equivalent continuum finite element for most practical space trusses. ESA

**N87-10930#** Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mathematics.
**CRITICAL ELEMENT CONCEPTS FOR COMPOSITE STRUCTURES**
K. L. REIFSNIDER *In* ESA Proceedings of an International Conference on Spacecraft Structures p 323-328 Apr. 1986
Avail: NTIS HC A19/MF A01

A critical element model approach to designing composite structures, e.g., for spacecraft, space platforms, launch vehicles and related equipment, is proposed. The modeling scheme combines mechanistic modeling of internal stress redistributions caused by damage with phenomenological (continuum) representations of property changes in critical elements to predict residual strength as a function of several types of loading. It utilizes a continuous summation scheme which is amenable to the automated computation of residual strength as a continuous function under cycle-dependent and time-dependent load environments which vary arbitrarily with time. The approach is successful for a wide variety of circumstances involving uniform stress fields. ESA

**N87-10933#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Fachbereich Technische Mechanik.
**DEBONDING ANALYSIS OF THERMALLY STRESSED FIBER-REINFORCED COMPOSITE MATERIALS**
F. G. BUCHHOLZ and K. H. SENGER *In* ESA Proceedings of an International Conference on Spacecraft Structures p 341-346 Apr. 1986
Avail: NTIS HC A19/MF A01

The effects of two ways of micromechanical modeling on the debonding analysis of thermally stressed unidirectionally fiber-reinforced composite materials are investigated. The models are a simple single circular unit cell and a more complex hexagonal unit cell embedded in the surrounding compound, as different orders of approximation to a real composite material. Correlation between the thermally induced elastic strain energy and the energy release rate of a curved interface crack, debonding an individual fiber from the adherent matrix material in both models is studied. The influence of increasing fiber volume fractions on the debonding behavior is assessed. Results show that the elastic strain energies induced in the models nearly coincide, although they differ distinctly in their geometrical contours and boundary conditions. For fiber volume fractions 10% it is shown that only the more complex model can deliver relevant results for the thermally induced plane strain debonding process in a real material. ESA

**N87-10957#** Groningen Rijksuniversiteit (Netherlands). Dept. of Mathematics.
**LARGE FLEXIBLE SPACE STRUCTURES: SOME SIMPLE MODELS**
J. BONTSEMA 1986 27 p
(TW-269; B8666169; ETN-86-98503) Avail: NTIS HC A03/MF A01

Simple models of large flexible space structures are used to study the effect of flexibility and damping. The models are a one dimensional flexible beam (Euler-Bernouilli) and two flexible beams [illegible] that the thickness of the disk in the direction of the beams is zero. Partial differential equations are derived for these structures and it is proved that the equations are well posed. Equations for the eigenfrequencies and eigenmodes of the structures are given and the controls and observations are discussed. As an example for finite dimensional control design the method of Curtain (1983) is discussed. ESA

**N87-11717*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**RECENT EXPERIENCES IN MULTIDISCIPLINARY ANALYSIS AND OPTIMIZATION, PART 1**
J. SOBIESKI, comp. 1984 517 p Symposium held in Hampton, Va., 24-26 Apr. 1984
(NASA-CP-2327-PT-1; NAS 1.55:2327-PT-1) Avail: NTIS HC A22/MF A01 CSCL 01C

Papers presented at the NASA Symposium on Recent Experiences in Multidisciplinary Analysis and Optimization held at NASA Langley Research Center, Hampton, Virginia April 24 to 26, 1984 are given. The purposes of the symposium were to exchange information about the status of the application of optimization and associated analyses in industry or research laboratories to real life problems and to examine the directions of future developments. Information exchange has encompassed the following: (1) examples of successful applications; (2) attempt and failure examples; (3) identification of potential applications and benefits; (4) synergistic effects of optimized interaction and trade-offs occurring among two or more engineering disciplines and/or subsystems in a system; and (5) traditional organization of a design process as a vehicle for or an impediment to the progress in the design methodology.

**N87-11750*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**RECENT EXPERIENCES IN MULTIDISCIPLINARY ANALYSIS AND OPTIMIZATION, PART 2**
J. SOBIESKI, comp. 1984 509 p Symposium held in Hampton, Va., 24-26 Apr. 1984
(NASA-CP-2327-PT-2; L-15830; NAS 1.55:2327-PT-2) Avail: NTIS HC A22/MF A01 CSCL 01C

The papers presented at the NASA Symposium on Recent Experiences in Multidisciplinary Analysis and Optimization held at NASA Langley Research Center, Hampton, Virginia, April 24 to 26, 1984 are given. The purposes of the symposium were to exchange information about the status of the application of optimization and the associated analyses in industry or research laboratories to real life problems and to examine the directions of future developments.

**N87-11761*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**IDEAS: A MULTIDISCIPLINARY COMPUTER-AIDED CONCEPTUAL DESIGN SYSTEM FOR SPACECRAFT**
M. J. FEREBEE, JR. *In its* Recent Experiences in Multidisciplinary Analysis and Optimization, Part 2 21 p 1984
Avail: NTIS HC A22/MF A01 CSCL 22B

During the conceptual development of advanced aerospace vehicles, many compromises must be considered to balance economy and performance of the total system. Subsystem tradeoffs may need to be made in order to satisfy system-sensitive attributes. Due to the increasingly complex nature of aerospace systems, these trade studies have become more difficult and time-consuming to complete and involve interactions of ever-larger numbers of subsystems, components, and performance parameters. The current advances of computer-aided synthesis, modeling and analysis techniques have greatly helped in the evaluation of competing design concepts. Langley Research Center's Space Systems Division is currently engaged in trade studies for a variety of systems which include advanced ground-launched space transportation systems, space-based orbital transfer vehicles, large space antenna concepts and space stations. The need for engineering analysis tools to aid in the rapid synthesis and evaluation of spacecraft has led to the development of the Interactive Design and Evaluation of Advanced Spacecraft (IDEAS) computer-aided design system. The ADEAS system has been used to perform trade studies of competing technologies and requirements in order to pinpoint possible beneficial areas for research and development. IDEAS is presented as a multidisciplinary tool for the analysis of advanced space systems. Capabilities range from model generation and structural and thermal analysis to subsystem synthesis and performance analysis. Author

**N87-11765*#** Engineering Mechanics Association, Inc., Palo Verde, Calif.
**COMPONENT TESTING FOR DYNAMIC MODEL VERIFICATION**
T. K. HASSELMAN and J. D. CHROSTOWSKI *In* NASA. Langley Research Center Recent Experiences in Multidisciplinary Analysis and Optimization, Part 2 15 p 1984
Avail: NTIS HC A22/MF A01 CSCL 01A

Dynamic model verification is the process whereby an analytical model of a dynamic system is compared with experimental data, adjusted if necessary to bring it into agreement with the data, and then qualified for future use in predicting system response in a different dynamic environment. These are various ways to conduct model verification. The approach taken here employs Bayesian statistical parameter estimation. Unlike curve fitting, whose objective is to minimize the difference between some analytical function and a given quantity of test data (or curve), Bayesian estimation attempts also to minimize the difference between the parameter values of that funciton (the model) and their initial estimates, in a least squares sense. The objectives of dynamic model verification, therefore, are to produce a model which: (1) is in agreement with test data; (2) will assist in the interpretation of test data; (3) can be used to help verify a design; (4) will reliably predict performance; and (5) in the case of space structures, will facilitate dynamic control. Author

**N87-12602#** California Univ., Los Angeles. Dept. of Electrical Engineering.
**A MATHEMATICAL FORMULATION OF A LARGE SPACE STRUCTURE CONTROL PROBLEM Interim Report**
A. V. BALAKRISHNAN Sep. 1985 8 p
(Contract AF-AFOSR-0318-83)
(AD-A169950; AFOSR-86-0444TR) Avail: NTIS HC A02/MF A01 CSCL 22B

This paper presents an abstract-mathematical formulation of a Large Space Structure Control problem. The physical apparatus consists of a softly supported antenna attached to the space shuttle by a flexible beam-like truss. The control objective is to slew the antenna on command within the given accuracy and maintaining stability. The control forces and torques are applied at the shuttle end as well as the antenna end and in addition provision is made for a small number of 2-axis proof-mass actuators along the beam. The beam motion is modelled by partial differential equations. Of the variety of control problems possible we touch only on the time-optimal probable. Author (GRA)

**N87-13484#** Engineering System International, Rungis (France).
**APPLICATION OF DYNAMIC ELEMENTS AND CONTINUUM METHODS TO LARGE SPACE STRUCTURES, VOLUME 1 Final Report**
A. BOSSAVIT, J. CLINCKEMAILLIE, E. HAUG, J. DUBOIS, DOWLATYARI, and Y. OUALI Paris, France ESA Dec. 1985 214 p
(Contract ESTEC-5209/82-NL-PB(SC))
(ED/82-362/RD-VOL-1; ESA-CR(P)-2217-VOL-1; ETN-86-98150)
Avail: Issuing Activity

Methods for the analysis of complex and large structures are reviewed. Classical numerical approaches are analyzed (Ritz methods, weighted residuals, boundary integrals) and substitute continuum and reduction methods are considered. The continuum methods are evaluated for application to a large space truss. It is concluded that lower order continua (for example: equivalent finite elements) form a sufficiently accurate basis for practical representations of large space trusses. Improved equivalent finite elements are identified and are recommended. ESA

**N87-13485#** Engineering System International, Rungis (France).
**APPLICATION OF DYNAMIC ELEMENTS AND CONTINUUM METHODS TO LARGE SPACE STRUCTURES, VOLUME 2 Final Report**
A. BOSSAVIT, J. CLINCKEMAILLIE, E. HAUG, J. DUBOIS, DOWLATYARI, and Y. OUALI Paris, France ESA Dec. 1985 293 p
(Contract ESTEC-5209/82-NL-PB(SC))
(ED/82-362/RD-VOL-2; ESA-CR(P)-2217-VOL-2; ETN-86-98151)
Avail: NTIS HC A13/MF A01

Methods for the analysis of complex and large structures are reviewed. Dynamic synthesis and reduction methods taking the symmetry of the structure into account are considered. Improvements of the accuracy of dynamic elements (bar, continuum, beam) by a better discretization of the mass matrix are identified. The two identified approaches (Stavrinidis and Second Order) can reduce the error in frequency, stresses, etc., in typical cases by a factor of more than 2. It is recommended to further explore these improvements since significant accuracy can be achieved with no extra computational effort. ESA

**N87-14059*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**THE IDENTIFICATION OF A DISTRIBUTED PARAMETER MODEL FOR A FLEXIBLE STRUCTURE**
H. T. BANKS (Brown Univ., Providence, R. I.), S. S. GATES (Draper (Charles Stark) Lab., Inc., Cambridge, Mass.), I. G. ROSEN (University of Southern California, Los Angeles.), and Y. WANG Oct. 1986 44 p
(Contract NAS1-17070; NAS1-18107; NAG1-517; NSF MCS-85-04316; AF-AFOSR-84-0398; AF-AFOSR-84-0393)
(NASA-CR-178199; ICASE-86-71; NAS 1.26:178199) Avail: NTIS HC A03/MF A01 CSCL 72B

A computational method is developed for the estimation of parameters in a distributed model for a flexible structure. The structure we consider (part of the RPL experiment) consists of a cantilevered beam with a thruster and linear accelerometer at the free end. The thruster is fed by a pressurized hose whose horizontal motion effects the transverse vibration of the beam. The Euler-Bernoulli theory is used to model the vibration of the beam and treat the hose-thruster assembly as a lumped or point mass-dashpot-spring system at the tip. Using measurements of linear acceleration at the tip, it is estimated that the parameters (mass, stiffness, damping) and a Voight-Kelvin viscoelastic structural damping parameter for the beam using a least squares fit to the data. Spline based approximations to the hybrid (coupled ordinary and partial differential equations) system are considered; theoretical convergence results and numerical studies with both simulation and actual experimental data obtained from the structure are presented and discussed. Author

**N87-16026*#** TRW, Inc., Redondo Beach, Calif.
**APPLICATION OF PHYSICAL PARAMETER IDENTIFICATION TO FINITE ELEMENT MODELS**
ALLEN J. BRONOWICKI, MICHAEL S. LUKICH, and STEVEN P. KURITZ *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 187-206 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 12A

A time domain technique for matching response predictions of a structural dynamic model to test measurements is developed. Significance is attached to prior estimates of physical model parameters and to experimental data. The Bayesian estimation procedure allows confidence levels in predicted physical and modal parameters to be obtained. Structural optimization procedures are employed to minimize an error functional with physical model parameters describing the finite element model as design variables. The number of complete FEM analyses are reduced using approximation concepts, including the recently developed convoluted Taylor series approach. The error function is represented in closed form by converting free decay test data to a time series model using Prony' method. The technique is demonstrated on simulated response of a simple truss structure. Author

**N87-16036*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**COFS 3: MULTIBODY DYNAMICS AND CONTROL TECHNOLOGY**
ROBERT LETCHWORTH and PAUL E. MCGOWAN *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 347-370 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 20K

COFS 3 is the third project within the Control of Flexible Structures (COFS) program. It deals with developing multibody dynamics and control technology for large space structures. It differs from COFS 1 and 2 in two respects. First, it addresses a more complex class of structure, and second it is basically a scale model ground test and analysis program while COFS 1 and 2 feature Shuttle flight experiments. The specific technology thrusts within COFS 3 are model sensitivities, test methods, analysis validation, systems identification, and vibration suppression. The COFS 3 project will develop the methods for using dynamically scaled models and analysis to predict the structural dynamics of large space structures. The project uses the space station as a focus because it is typical of the structures of interest and provides the first opportunity to obtain full-scale on-orbit dynamics data. Author

**N87-16040*#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.
**SYSTEM IDENTIFICATION FOR MODELING FOR CONTROL OF FLEXIBLE STRUCTURES**
EDWARD METTLER and MARK MILMAN *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 419-429 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 22B

The major components of a design and operational flight strategy for flexible structure control systems are presented. In this strategy an initial distributed parameter control design is developed and implemented from available ground test data and on-orbit identification using sophisticated modeling and synthesis techniques. The reliability of this high performance controller is directly linked to the accuracy of the parameters on which the design is based. Because uncertainties inevitably grow without system monitoring, maintaining the control system requires an active on-line system identification function to supply parameter updates and covariance information. Control laws can then be modified to improve performance when the error envelopes are decreased. In terms of system safety and stability the covariance information is of equal importance as the parameter values themselves. If the on-line system ID function detects an increase in parameter error covariances, then corresponding adjustments must be made in the control laws to increase robustness. If the error covariances exceed some threshold, an autonomous calibration sequence could be initiated to restore the error enveloped to an acceptable level. Author

**N87-16042*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**COMPUTER-AIDED DESIGN AND DISTRIBUTED SYSTEM TECHNOLOGY DEVELOPMENT FOR LARGE SPACE STRUCTURES**
ERNEST S. ARMSTRONG and SURESH M. JOSHI *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 441-456 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 22B

Proposed large space structures have many characteristics that make them difficult to analyze and control. They are highly flexible, with components mathematically modeled by partial differential equations or very large systems of ordinary differential equations. They have many resonant frequencies, typically low and closely spaced. Natural damping may be low and/or improperly modeled. Coupled with stringent operational requirements of orientation, shape control, and vibration suppression, and the inability to perform adequate ground testing, these characteristics present an unconventional identification and control design problem to the systems theorist. Some of the research underway within Langley's Spacecraft Control Branch, Guidance and Control Division aimed at developing theory and algorithms to treat large space structures systems identification and control problems is described. The research areas to be considered are computer-aided design algorithms, and systems identification and control of distributed systems. Author

**N87-16045*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**MULTIDISCIPLINARY ANALYSIS OF ACTIVELY CONTROLLED LARGE FLEXIBLE SPACECRAFT**
PAUL A. COOPER, JOHN W. YOUNG, and THOMAS R. SUTTER *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 495-514 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 22B

The control of Flexible Structures (COFS) program has supported the development of an analysis capability at the Langley Research Center called the Integrated Multidisciplinary Analysis Tool (IMAT) which provides an efficient data storage and transfer

capability among commercial computer codes to aid in the dynamic analysis of actively controlled structures. IMAT is a system of computer programs which transfers Computer-Aided-Design (CAD) configurations, structural finite element models, material property and stress information, structural and rigid-body dynamic model information, and linear system matrices for control law formulation among various commercial applications programs through a common database. Although general in its formulation, IMAT was developed specifically to aid in the evaluation of the structures. A description of the IMAT system and results of an application of the system are given. Author

**N87-16971*#** Colby Coll., Waterville, Maine. Dept. of Physics and Astronomy.
**LEO HIGH VOLTAGE SOLAR ARRAY ARCING RESPONSE MODEL Interim Report, Feb. 1987**
ROGER N. METZ Feb. 1987 32 p
(Contract NAG3-576)
(NASA-CR-180073; NAS 1.26:180073) Avail: NTIS HC A03/MF A01 CSCL 09A

A series of mathematical models were developed that describe the electrical behavior of a large solar cell array floating electrically in the low Earth orbit (LEO) space plasma and struck by an arc at a point of negative bias. There are now three models in this series: ARCII, which is a fully analytical, linearized model; ARCIII, which is an extension of ARCIII that includes solar cell inductance as well as load reactance; Nonlinear ARC, which is a numerical model able to treat effects such as non-linearized, i.e., logarithmic solar cell I/V characteristics, conductance switching as a solar cell crosses plasma ground on a voltage excursion and non-ohmic plasma leakage current collection. Author

**N87-17810#** Toronto Univ. (Ontario). Inst. for Aerospace Studies.
**COMBINED ORBIT/ATTITUDE DETERMINATION FOR LOW-ALTITUDE SATELLITES**
PAUL WINCHESTER CHODAS Dec. 1986 275 p
(UTIAS-320; ISSN-0082-5255; AD-B109229L) Avail: NTIS HC A12/MF A01

Orbit and attitude determination are studied as a single combined estimation problem, and the coupling between the orbit and attitude dynamics is included. The focus is on missions with large spacecraft in low-altitude Earth orbits. The orbit and attitude motions are coupled by the gravitational forces and torques and the aerodynamic forces and torques, which are the dominant environment effects for the class of missions under consideration. A computer simulation of the combined orbit and attitude determination problem, including the coupled orbit and attitude equations of motion, was implemented. Two combinations of measurement types are studied: ground tracking with onboard star observations, and onboard tracking of known landmarks combined with star observations. The effect of the dynamic orbit-attitude coupling on the position and attitude estimates was studied. It is shown that the inclusion of the dynamic coupling improves the position and attitude estimates substantially. Using covariance analysis techniques, it is demonstrated that the attitude uncertainties are unrealistically small without coupling, and that this lead to divergence in the attitude estimate. The use of process noise to prevent this divergence in the attitude estimate is studied. A process noise model which includes some of the coupling effects is also applied to the problem. Author

**N87-20066*#** Systems Science and Software, La Jolla, Calif.
**A UNIFIED APPROACH TO COMPUTER ANALYSIS AND MODELING OF SPACECRAFT ENVIRONMENTAL INTERACTIONS**
I. KATZ, M. J. MANDELL, and J. J. CASSIDY *In* JPL, Space Technology Plasma Issues in 2001 p 113-125 1 Oct. 1986
Avail: NTIS HC A20/MF A01 CSCL 22B

A new, coordinated, unified approach to the development of spacecraft plasma interaction models is proposed. The objective is to eliminate the unnecessary duplicative work in order to allow researchers to concentrate on the scientific aspects. By streamlining the developmental process, the interchange between theories and experimentalists is enhanced, and the transfer of technology to the spacecraft engineering community is faster. This approach is called the UNIfied Spacecraft Interaction Model (UNISIM). UNISIM is a coordinated system of software, hardware, and specifications. It is a tool for modeling and analyzing spacecraft interactions. It will be used to design experiments, to interpret results of experiments, and to aid in future spacecraft design. It breaks a Spacecraft Ineraction analysis into several modules. Each module will perform an analysis for some physical process, using phenomenology and algorithms which are well documented and have been subject to review. This system and its characteristics are discussed. E.R.

**N87-20084*#** Air Force Geophysics Lab., Hanscom AFB, Mass.
**COMPUTER MODELS OF THE SPACECRAFT WAKE Abstract Only**
A. G. RUBIN, M. HEINEMANN, M. TAUTZ (RADEX, Inc., Bedford, Mass.), and D. COOKE *In* JPL, Space Technology Plasma Issues in 2001 p 313 1 Oct. 1986
Avail: NTIS HC A20/MF A01 CSCL 09B

Until recently, computations of space plasma flow over a spacecraft have been unstable for ratios of spacecraft dimension to Debye length typical of the low Earth orbit environment. Calculations are presented of the spacecraft/environment interaction based on two computer codes, MACH and POLAR. MACH, an inside-out particle tracking code, was developed for the purpose of validating the physics of POLAR in regimes where these are no comprehensive theoretical or experimental results. While the spacecraft which can be treated by MACH are restricted to simple geometries, the methodology is more fundamental than POLAR. MACH generates self-consistent solutions within the context of quasisteady Vlasov plasma flow and achieves Debye ratios previously unobtainable. POLAR uses a three-dimensional finite-element representation of the vehicle in a staggered mesh. The plasma sheath is modeled by outside-in particle tracking. Solutions for the plasma flow, wake and vehicle charging are obtained by Vlasov-Poisson iteration; charge stabilization techniques make the results virtually insensitive to the Debye ratio. POLAR reproduces the Laframboise static plasma solutions for sperical probes and fits the Makita-Kuriki probe data for spheres in a flowing plasma in regions where comparisons are valid. POLAR and MACH solutions for the particle and electrostatic potential structure of the wake of a charged disk in a low-altitude flow are shown for Mach numbers 4, 5, and 8. New features of the solutions include ion focussing in the wake and a definitive determination of the sheath edge in the wake which shows that the sheath is not an equipotential. Author

# 03

## STRUCTURAL CONCEPTS

Includes analyses and descriptions of different Space Station structural concepts, arrangements, testing, methods of construction and/or manufacturing and specific rotary joints, structural nodes, and columns.

**A87-11842*** Lockheed Missiles and Space Co., Sunnyvale, Calif.
**DEVELOPMENT OF SPACE STATION STRUT DESIGN**
R. R. JOHNSON, R. M. BLUCK, A. M. C. HOLMES, and M. H. KURAL (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) SAMPE Quarterly (ISSN 0036-0821), vol. 17, July 1986, p. 1-9.
(Contract NAS1-17660)

Candidate Space Station struts exhibiting high stiffness (38-40 msi modulus of elasticity) were manufactured and experimentally evaluated. One and two inch diameter aluminum-clad evaluation specimens were manufactured using a unique dry fiber resin injection process. Preliminary tests were performed on strut

elements having 80 percent high-modulus graphite epoxy and 20 percent aluminum. Performed tests included modulus of elasticity, thermal cycling, and coefficient of thermal expansion. The paper describes the design approach, including an analytical assessment of strut thermal deformation behavior. The major thrust of this paper is the manufacturing process which produces aluminum-clad struts with precisely controlled properties which can be fine-tuned after fabrication. An impact test and evaluation procedure for evaluating toughness is described. Author

**A87-13159**
**FABRICATION OF A SPACE STATION COMPOSITE TETRATRUSS MODEL**
J. F. DUBEL (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: International SAMPE Symposium and Exhibition, 31st, Los Angeles, CA, April 7-10, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 1469-1475.
Attention is given to the design, fabrication and assembly processes associated with a prototype composites-employing 'tetratruss' for Space Station-related use. Unidirectional and chopped fiber-reinforced composites have been chosen for the fabrication of the truss structure's tubular struts and fittings, respectively. The tubes' unidirectional material will be plied in order to yield the requisite longitudinal modulus and thermal expansion coefficient while retaining acceptable transverse modulus; the chopped graphite fiber reinforced for the frame's nodes, tube ends and hinge fittings will produce somewhat greater thermal expansion. The overall design, test, verification, fabrication and assembly process data generated by this prototype will be used as a basis for Space Station composite primary structure cost projections. O.C.

**A87-13458*** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**VIBRATION SUPPRESSION OF PLANAR TRUSS STRUCTURES UTILIZING UNIFORM DAMPING CONTROL**
G. C. ANDERSEN (NASA, Langley Research Center, Hampton, VA) and L. M. SILVERBERG (North Carolina State University, Raleigh) IN: 1986 American Control Conference, 5th, Seattle, WA, June 18-20, 1986, Proceedings. Volume 3 . New York, Institute of Electrical and Electronics Engineers, 1986, p. 2040-2047. refs
A variety of methods has been devised for vibrational control of a structure using both passive and active controls. Presented in this paper is a relatively new method for vibration suppression, uniform damping control. This method consists of implementing a control law which tends to dampen each vibrational mode of the structure at the same desirable exponential rate. The unique aspects of this method are that the control law is not explicitly dependent on the structural stiffness, the control forces are directly proportional to the distribution of the structural mass, and the control law is natural and decentralized. The control law was applied to a flexible planar truss structure and the various aspects of implementation of the control law examined are: actuator/sensor number, placement, and the impact of the actuator/sensor number and placement on the necessary control 'power' requirements such as peak power loads, total power requirements, etc. Also examined are the effects of using a limited number of active members in terms of the vibrational performance when compared with the 'ideal' distributed control law. Author

**A87-14312*** Massachusetts Inst. of Tech., Cambridge.
**FUNDAMENTALS AND ADVANCES IN THE DEVELOPMENT OF REMOTE WELDING FABRICATION SYSTEMS**
J. E. AGAPAKIS (Automatix, Inc., R&D Group, Billerica; MIT, Cambridge, MA), K. MASUBUCHI (MIT, Cambridge, MA), and C. VON ALT (Woods Hole Oceanographic Institute, MA) Welding Journal (ISSN 0043-2296), vol. 65, Sept. 1986, p. 21-32. MIT-NASA-supported research. refs
Operational and man-machine issues for welding underwater, in outer space, and at other remote sites are investigated, and recent process developments are described. Probable remote welding missions are classified, and the essential characteristics of fundamental remote welding tasks are analyzed. Various possible operational modes for remote welding fabrication are identified, and appropriate roles for humans and machines are suggested. Human operator performance in remote welding fabrication tasks is discussed, and recent advances in the development of remote welding systems are described, including packaged welding systems, stud welding systems, remotely operated welding systems, and vision-aided remote robotic welding and autonomous welding systems. C.D.

**A87-15817*#** National Aeronautics and Space Administration, Washington, D.C.
**SPACE CONSTRUCTION RESULTS - THE EASE/ACCESS FLIGHT EXPERIMENT**
I. BEKEY (NASA, Office of Space Flight, Washington, DC) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 6 p.
(IAF PAPER 86-26)
NASA ground and flight test activities aimed at the development of in-space construction techniques for the assembly of Space-Station-sized structures are described. In particular, attention is given to the EASE and ACCESS flight experiments, the ground and water tank program, and operations in-flight including instrumentations. The baseline experiments demonstrate that erectable structures can be assembled effectively by astronauts in EVA. The average assembly time for a 45-foot truss was 25.5 minutes; the assembly rate was 3.6 struts per minute. V.L.

**A87-16163**
**DESIGN AND MANUFACTURING ASPECTS OF TUBULAR CARBON FIBRE COMPOSITE/TITANIUM BONDED JOINTS**
J. FRANZ and H. LAUBE (Messerschmitt-Boelkow-Blohm GmbH, Ottobrunn, West Germany) (Imperial College of Science and Technology and Ciba-Geigy Plastics, International Symposium on Joining and Repair of Fibre-Reinforced Plastics, London, England, Sept. 10, 11, 1986) Composite Structures (ISSN 0263-8223), vol. 6, no. 1-3, 1986, p. 183-196.
The structure of the satellite SPAS-01 consists of a framework built by carbon fiber composite/titanium strut and node elements. The key point of the whole structure is the connection between the carbon fiber composite tube and the titanium end fitting, which has been designed and constructed in the form of a scarf, double-shear bonded joint. The present paper describes the structural requirements and their verification in the phases of design, analysis, test and fabrication of the satellite structure. Author

**A87-25680#**
**EXPERIMENTAL CHARACTERIZATION OF PASSIVELY DAMPED JOINTS FOR SPACE STRUCTURES**
JACKY PRUCZ (West Virginia University, Morgantown), A. D. REDDY, L. W. REHFIELD (Georgia Institute of Technology, Atlanta), and R. W. TRUDELL (McDonnell Douglas Astronautics Co., Huntington Beach, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 23, Nov.-Dec. 1986, p. 568-575. refs
(Contract F49620-83-C-0017)
An innovative means to enhance the inherent damping in structures is provided by the designed-in incorporation of viscoelastic materials in joints. The damping and stiffness properties of such joints have been experimentally evaluated at room temperature and low frequencies on representative specimens. The test data show that proper design configurations can yield significant damping benefits without unacceptable stiffness penalties. Three different test methods and a new data reduction procedure have been utilized in the experimental program. Two of the three methods are new. A simplified steady-state technique and a sine-pulse propagation approach have been developed and applied in this research. The results show relatively low data scatter from repeated measurement sets, and there is good agreement among the different test methods. Author

**N87-10886#** European Space Agency, Paris (France).
**PROCEEDINGS OF AN INTERNATIONAL CONFERENCE ON SPACECRAFT STRUCTURES**
W. R. BURKE, comp. Apr. 1986 433 p In ENGLISH and FRENCH Conference held in Toulouse, France, 3-6 Dec. 1985
(ESA-SP-238; ISSN-0379-6566; ETN-86-98078) Avail: NTIS HC A19/MF A01

Spacecraft structural analysis, including dynamic analysis and tests, dynamical identification, and acoustics analysis; design engineering; and spacecraft construction materials were discussed. ESA

**N87-10890#** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Mechanical Systems Div.
**DESIGN AND VERIFICATION ACTIVITIES AND REQUIREMENTS FOR SPACECRAFT STRUCTURES**
C. STAVRINIDIS *In* ESA Proceedings of an International Conference on Spacecraft Structures p 27-33 Apr. 1986
Avail: NTIS HC A19/MF A01

The scope and associated cost related with spacecraft structures design and verification are discussed. These depend on such factors as the geometrical dimensions of the spacecraft, weight criticality and the degree of dynamic interaction of the spacecraft with the launch vehicle. For large complex spacecraft which often have significant dynamic interaction with the launch vehicle, structural design and verification usually require a combination of analysis, development testing, and qualification testing. ESA

**N87-10923#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**DEVELOPMENT OF DEPLOYABLE TRUSS CONCEPT FOR SPACE STATION**
H. S. GREENBERG (Rockwell International Corp., Downey, Calif.) and E. E. ENGLER *In* ESA Proceedings of an International Conference on Spacecraft Structures p 277-282 Apr. 1986
Avail: NTIS HC A19/MF A01

A single-fold, automatically deployable and retractable, square-shaped truss concept that is a candidate for the strongback of NASA's Space Station was developed. Compact stowage within a square-shaped housing is achieved by using folded longerons and telescoping diagonal members. Deployment or retraction is accomplished, bay by bay, in a controlled manner with root strength maintained at all times. Control is accomplished by motor-driven jack-screws operated by a controller. Power, data, and fluid utility lines can be integrated onto trays that unfold with the truss. To verify performance a kinematically representative ground test article version is used. ESA

**N87-10940#** Societe Nationale Industrielle Aerospatiale, Saint-Medard-en-Jalles (France).
**A METHOD OF STUDYING THE BEHAVIOR OF COMPOSITE MATERIALS IN SIMULATED SPACE ENVIRONMENTS [MOYEN D'ETUDE DU COMPORTEMENT EN AMBIANCE SPATIALE SIMULEE DE MATERIAUX COMPOSITES]**
F. ALBUGUES, P. PLOTARD, M. F. GOMEZ (Office National d'Etudes et de Recherches Aerospatiales, Toulouse, France), A. PAILLOUS, and M. D. JUDD (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA Proceedings of an International Conference on Spacecraft Structures p 393-397 Apr. 1986 In FRENCH
Avail: NTIS HC A19/MF A01

A method to evaluate the mechanical properties of composite spacecraft structural materials in simulated space vacuum, radiation, and thermal conditions was developed. It can irradiate in secondary vacuum a test batch of which a part is measured in situ and the rest afterwards. Different stages of aging due to UV and electron irradiation can be accounted for. ESA

**N87-11178*#** Old Dominion Univ., Norfolk, Va. Dept. of Civil Engineering.
**PASSIVE DAMPING CONCEPTS FOR SLENDER COLUMNS IN SPACE STRUCTURES Progress Report, period ending 1 Feb. 1985**
Z. RAZZAQ Feb. 1985 12 p
(Contract NAG1-336)
(NASA-CR-179807; NAS 1.26:179807) Avail: NTIS HC A02/MF A01 CSCL 20K

Research into the identification of potential passive damping concepts for use in very slender structural members was continued. The following damping concepts are under investigation: mass-string dampers; bright zinc chain; polyethylene tubing; external viscoelastic tape; brushes for electrostatic and frictional damping; suspended chambers with oil and discs; and hybrid concepts. Each of these concepts are briefly discussed. Author

**N87-11832#** British Aerospace Public Ltd. Co., Bristol (England). Space and Communications Div.
**A STUDY OF LARGE SPACE STRUCTURES**
N. FOSTER 5 Jul. 1982 45 p
(LR46869; ETN-86-97949) Avail: NTIS HC A03/MF A01

The structural design requirements for a large space structure are identified. The preferred structural model is the tetrahedral truss, capable of being deployed automatically or constructed using the Shuttle remote manipulator system. Preliminary analysis was performed to show how such a structure could be modelled to determine the structural characteristics. Aspects for investigation of the structural modelling are identified, including joint stiffness, thermal stability, manufacturing tolerances, deployment dynamics and dynamic interaction. ESA

**N87-14373*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**FOLDABLE SELF-ERECTING JOINT Patent**
T. E. PELISCHEK, inventor (to NASA) 7 Oct. 1986 8 p Filed 9 Mar. 1984 Supersedes N84-32424 (22 - 22, p 3542)
(NASA-CASE-MSC-20635-1; US-PATENT-4,615,637; US-PATENT-APPL-SN-588039; US-PATENT-CLASS-403-85; US-PATENT-CLASS-403-102; US-PATENT-CLASS-403-119; US-PATENT-CLASS-403-146; US-PATENT-CLASS-403-163; US-PATENT-CLASS-16-294; US-PATENT-CLASS-16-370) Avail: US Patent and Trademark Office CSCL 22B

The invention relates to a foldable self erecting joint which may be used to deploy the tetratruss frame of the proposed shuttle launched triangular space station. The frame must be folded into the payload bay of the space shuttle orbiter. To deploy the frame the tubes are automatically unfolded and once in position should remain safely. A pair of hinged, tubular members in which the hinging is located at corresponding portions of the members are used. The opposite edge portions are connected by spring-based toggle links which in the unfolded position of the members are nested against one of the members in substantial alignment and over-center for securely locking the joint in the unfolded position.
Official Gazette of the US Patent and Trademark Office

**N87-14413*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**SYNCHRONOUSLY DEPLOYABLE DOUBLE FOLD BEAM AND PLANAR TRUSS STRUCTURE Patent Application**
M. D. RHODES, inventor (to NASA) and J. M. HEDGEPETH, inventor (to NASA) 22 Aug. 1986 14 p
(NASA-CASE-LAR-13490-1; NAS 1.71:LAR-13490-1; US-PATENT-APPL-SN-899683) Avail: NTIS HC A02/MF A01 CSCL 84G

A deployable structure that synchronously deploys in both length and width is disclosed which is suitable for use as a structural component for orbiting space stations or large satellites. The structure is designed with maximum packing efficiency so that large structures may be collapsed and transported in the cargo bay of the Space Shuttle. The synchronous deployment feature allows the structure to be easily deployed in space by two astronauts, without a complex deployment mechanism. The

structure is made up of interconnected structural units, each generally in the shape of a parallelepiped. The structural units are constructed of structural members connected with hinged and fixed connections at connection nodes in each corner of the parallelepiped. Diagonal members along each face of the parallelepiped provide structural rigidity and are equipped with mid-length, self-locking hinges to allow the structure to collapse. The structure is designed so that all hinged connections may be made with simple clevis-type hinges requiring only a single degree of freedom, and each hinge pin is located along the centerline of its structural member for increased strength and stiffness. NASA

**N87-16059#** Lockheed Missiles and Space Co., Palo Alto, Calif.
**WAVE DISPERSION MECHANISMS IN LARGE SPACE STRUCTURES Final Report, Oct. 1983 - Oct. 1985**
K. C. PARK 25 Nov. 1985 7 p
(Contract F49620-83-C-0018)
(AD-A173967; LMSC-F104499; AFOSR-86-1007TR) Avail: NTIS HC A02/MF A01 CSCL 22B

This report describes an investigation into wave dispersion phenomena in large lattice space structures. Particular results were: (1) That local member dynamic characteristics significantly influence global dynamic response; (2) That it is possible to increase dispersion of wave energy in lattice-truss structures by adopting a nonuniform lattice construction; and (3) That local member dynamics characteristics require detailed modeling techniques which are capable of capturing member bending behavior in order to assess, realistically, the influence of local phenomena on global dynamic response. GRA

**N87-16323*#** Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
**EXTENDABLE RETRACTABLE TELESCOPIC MAST FOR DEPLOYABLE STRUCTURES**
M. SCHMID and M. AGUIRRE (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* NASA. Lewis Research Center The 20th Aerospace Mechanics Symposium p 13-29 May 1986
Avail: NTIS HC A14/MF A01 CSCL 22B

The Extendable and Retractable Mast (ERM) which is presently developed by Dornier in the frame of an ESA-contract, will be used to deploy and retract large foldable structures. The design is based on a telescopic carbon-fiber structure with high stiffness, strength and pointing accuracy. To verify the chosen design, a breadboard model of an ERM was built and tested under thermal vacuum (TV)-conditions. It is planned as a follow-on development to manufacture and test an Engineering Model Mast. The Engineering Model will be used to establish the basis for an ERM-family covering a wide range of requirements. Author

**N87-16338*#** Sperry Corp., Phoenix, Ariz. Space Systems Div.
**SPACE STATION ROTARY JOINT MECHANISMS**
GLEN W. DRISKILL *In* NASA. Lewis Research Center The 20th Aerospace Mechanics Symposium p 241-251 May 1986
Avail: NTIS HC A14/MF A01 CSCL 13I

The mechanism which will be used on the space station to position the solar arrays and radiator panels for Sun pointing and Sun avoidance is described. The unique design features will be demonstrated on advanced development models of two of the joints being fabricated under contract to NASA-MSFC. Author

**N87-16870*#** Astro Aerospace Corp., Carpinteria, Calif.
**EVALUATION OF PACTRUSS DESIGN CHARACTERISTICS CRITICAL TO SPACE STATION PRIMARY STRUCTURE Final Report**
JOHN M. HEDGEPETH 20 Feb. 1987 74 p
(Contract NAS1-17536)
(NASA-CR-178171; NAS 1.26:178171; AAC-TN-1147-REV-A)
Avail: NTIS HC A04/MF A01 CSCL 22A

Several aspects of the possible application of the Pactruss concept to the primary truss structure of the space station are investigated. Estimates are made of the loads and hinge moments in deploying diagonal members as full deployment is approached. Included are the effects of beam columning and compliance of the surrounding structure. Requirements for joint design are suggested and a two-stage mid-diagonal latching hinge concept is described or analyzed. The problems with providing the experimental and theoretical tools needed for assuring reliable synchronous deployment are discussed and a first attempt at high-fidelity analytical simulation with NASTRAN is described. An alternative construction scenario in which the entire dual-keel truss structure is deployed as a single Shuttle payload is suggested. Author

**N87-18595*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**LOCKING HINGE Patent Application**
CLARENCE J. WESSELSKI, inventor (to NASA) 29 Oct. 1986 16 p
(NASA-CASE-MSC-21056-1; NAS 1.71:MSC-21056-1; US-PATENT-APPL-SN-924397) Avail: NTIS HC A02/MF A01 CSCL 22B

The space station configuration currently being studied utilizes structures which require struts to be hinged in the middle in stowed configuration and locked into place in the deployed configuration. Since there are hundreds of hinges involved, it is necessary that they have simple, positive locking features with a minimum of joint looseness or slack. The instant invention comprises two similar housings hinged together with a spring loaded locking member which assists in making the lock as well as breaking it. The instant invention comprises a bracket hinge and bracket members with a spring biased and movable locking member. The locking or latch member has ear parts received in locking openings where wedging surfaces on the ear parts cooperate with complimentary surfaces on the bracket members for bringing the bracket members into a tight end-to-end alignment when the bracket members are in an extended position. When the locking member is moved to an unlocking position, pivoting of the hinge about a pivot pin automatically places the locking member to retain the locking member in an unlocked position. In pivoting the hinge from an extended position to a folded position, longitudinal spring members are placed under tension over annular rollers so that the spring tension in a folded position assists in return of the hinge from a folded position to an extended position. Novelty lies in the creation of a locking hinge which allows compact storage and easy assembly of structural members having a minimal number of parts. NASA

**N87-19435#** McDonnell-Douglas Astronautics Co., Huntington Beach, Calif.
**PASSIVELY DAMPED JOINTS FOR ADVANCED SPACE STRUCTURES Final Report, 15 May 1983 - 15 Jan. 1986**
JAMES H. PEEBLES, RICHARD W. TRUDELL, CREED E. BLEVINS, and JACKY C. PRUCZ 28 Mar. 1986 190 p
(Contract F49620-83-C-0117)
(AD-A174914; MDC-H2334; AFOSR-86-2075TR) Avail: NTIS HC A09/MF A01 CSCL 22B

This report includes: (1) the development of a viscoelastic materials selection guide for this research activity; (2) the development of an analytic statics model of the joint specimens; (3) the designs, fabrication and testing of 21 viscoelastic joint specimens, including the development of a new material; (4) the procurement, fabrication and assembly of test equipment for the test program at the Georgia Institute of Technology as well as the development of data reduction computer programs; (5) the development and successful demonstration of transient pulse and simplified steady state methods for evaluating energy losses in joints; and (6) the performance of outgassing tests on several viscoelastic materials. GRA

# 04

# THERMAL CONTROL

Includes descriptions of analytical techniques, passive and active thermal control techniques, external and internal thermal experiments and analyses and trade studies of thermal requirements.

**A87-15197**
**CONTROLLING WASTE HEAT IN MILITARY SPACECRAFT**
J. H. BRAHNEY Aerospace Engineering (ISSN 0736-2536), vol. 6, Aug. 1986, p. 23-29.

The purpose of a spacecraft thermal management system (TMS) is to gather waste heat and reject it from the vehicle; attention is presently given to the anticipated compounding of already severe military space platform TMS requirements by the incorporation of a high pulsed power heat rejection capability. An evaluation is conducted of several TMS configurations that appear promising; the capillary pumped-loop type being noteworthy. Also noted are radiator systems and TMSs incorporating heat storage media. O.C.

**A87-15935#**
**ASSEMBLY OF THERMOELASTIC CONTINUOUS ELEMENTS**
C. ARDUINI (Roma, Universita, Rome, Italy) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 31 p. refs
(IAF PAPER 86-207)

Techniques for assembling the continuous-scheme models of thermoelastic beams and plates derived by Arduini and Ponzi (1982) and Arduini et al. (1985) into more complex structures are developed analytically and demonstrated. Both modal-synthesis and distributed-element approaches are extended to treat thermal and thermostructural problems, and numerical results for the static heating of a tubular triangular beam are presented graphically. T.K.

**A87-15936#**
**NONLINEAR EFFECTS IN THERMAL CONDUCTION PROBLEMS OF LARGE SPACE STRUCTURES**
P. SANTINI (Roma, Universita, Rome, Italy) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 12 p.
(IAF PAPER 86-208)

Some of the most important nonlinearities affecting the thermal behavior of space structures are considered and discussed. The basic equations for a single member are written, and the complete system in steady condition is described. Several methods of numerical solutions are considered (successive approximations; artificial unsteady; Newton Raphson), and the relevant relative merits are analyzed. Typical examples on a simple structure are carried out, and final conclusions are drawn. Author

**A87-18175*** Grumman Aerospace Corp., Bethpage, N.Y.
**SOLAR DYNAMIC SPACE POWER SYSTEM HEAT REJECTION**
A. W. CARLSON, E. GUSTAFSON (Grumman Aerospace Corp., Bethpage, NY), and K. L. MCLALLIN (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 2060-2071. refs
(Contract NAS3-24665)

A radiator system concept is described that meets the heat rejection requirements of the NASA Space Station solar dynamic power modules. The heat pipe radiator is a high-reliability, high-performance approach that is capable of erection in space and is maintainable on orbit. Results are present of trade studies that compare the radiator system area and weight estimates for candidate advanced high performance heat pipes. The results indicate the advantages of the dual-slot heat pipe radiator for high temperature applications as well as its weight-reduction potential over the range of temperatures to be encountered in the solar dynamic heat rejection systems. Author

**A87-18266**
**THE INFLUENCE OF INTERSTITIAL MEDIA ON SPACECRAFT THERMAL CONTROL**
L. S. FLETCHER (Texas A & M University, College Station) IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 527-532. refs

Thermal control is of significant importance in the design and operation of most aerospace systems. The importance of thermal protection systems and the concern for energy efficiency suggest the need for more reliable knowledge of energy transfer across metallic junctions with and without interstitial media. This paper discusses recent investigations of thermal contact conductance involving both gaseous and nongaseous interstitial media in terms of thermal enhancement and thermal isolation characteristics. Author

**A87-18277**
**A FLUID-DYNAMIC RADIATOR SYSTEM FOR A FUTURE LARGE SCALE SPACE STATION**
Y. KOBAYASHI (Tsukuba, University, Sakura, Japan) IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 615-620. refs

A new type of fluid-dynamic radiator system employing heat pipe heat rejector (HPHR) is proposed for a future large scale space station which will dissipate more than a hundred kilowatt of heat energy to the space. One of the significant features of this system is that it works both as a radiator and a refrigerator depending on the thermal environment of the spacecraft. A thermodynamic cycle of HPHR is composed of two constant-volume and two adiabatic changes under a vapor-liquid coexisting condition. Therefore, the system can be operable effectively at relatively low pressure ranges of less than 1.0 MPa by selecting a suitable working fluid. This fact will result in a high coefficient of performance as a heat rejecting system equipped with no external compresser. Author

**A87-25679#**
**CONCEPTUAL FLUID-DYNAMIC HEAT REJECTION SYSTEM FOR SPACE STATION APPLICATION**
YASUNORI KOBAYASHI (Tsukuba, University, Sakura, Japan) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 23, Nov.-Dec. 1986, p. 561-567. Previously cited in issue 17, p. 2472, Accession no. A85-37669. refs

**A87-31213#**
**THERMAL CONTROL SYSTEMS FOR SPACECRAFT INSTRUMENTATION**
G. P. PETERSON (Texas A & M University, College Station) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, Jan.-Feb. 1987, p. 7-13. Previously cited in issue 14, p. 1982, Accession no. A83-32736. refs

**N87-10184*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**EFFECTS OF THERMAL CYCLING ON GRAPHIE-FIBER-REINFORCED 6061 ALUMINUM**
G. A. DRIES (PRC Kentron, Inc., Hampton, Va.) and S. S. TOMPKINS Oct. 1986 29 p
(NASA-TP-2612; L-16139; NAS 1.60:2612) Avail: NTIS HC A03/MF A01 CSCL 11D

Graphite-reinforced aluminum alloy metal-matrix composites are among materials being considered for structural components in dimensionally stable space structures. This application requires materials with low values of thermal expansions and high specific stiffnesses. They must remain stable during exposures to the space environment for periods extending to 20 years. The effects of thermal cycling on the thermal expansion behavior and mechanical

properties of Thornel P100 graphite 6061 aluminum composites, as fabricated and after thermal processing to eliminate thermal strain hysteresis, have been investigated. Two groups of composites were studied: one was fabricated by hot roll bonding and the other by diffusion bonding. Processing significantly reduced strain hysteresis during thermal cycling in both groups and improved the ultimate tensile strength and modulus in the diffusion-bonded composites. Thermal cycling stabilized the as-fabricated composites by reducing the residual fabrication stress and increased the matrix strength by metallurgical aging. Thermal expansion behavior of both groups after processing was insensitive to thermal cycling. Data scatter was too large to determine effects of thermal cycling on the mechanical properties. The primary effects of processing and thermal cycling can be attributed to changes in the metallurgical condition and stress state of the matrix. Author

**N87-14393*#** Lockheed Missiles and Space Co., Sunnyvale, Calif. Spacecraft Thermodynamics.
**SOLAR MAXIMUM THERMAL SURFACE ASSESSMENT**
G. D. RHOADS *In* NASA. Goddard Space Flight Center Proceedings of the SMRM Degradation Study Workshop p 343-355 1985
Avail: NTIS HC A16/MF A01 CSCL 22B

The inflight repair of the Solar Maximum Spacecraft provided the first opportunity to make actual measurements of thermal control surfaces after 4 years exposure in low Earth orbit. Defective hardware was replaced by astronauts and returned to Earth while protected from reentry damage in the Shuttle Payload bay. A preliminary thermal surface assessment was made soon after retrieval in support of Space Telescope and other current spacecraft programs. This included visual examination and measurement of Kapton and Teflon film to determine change in thermal radiative properties after 4 years exposure to solar radiation and reaction with atomic oxygen. Comparative measurements were made with a portable solar reflectometer used for inspection of spacecraft hardware. Post flight measurements and observations reveal significant surface changes that further confirm Kapton mass loss predictions made prior to Solar Maximum repair. Details of thermal surface application, measurements and experimental results are presented and discussed. Author

**N87-16949#** Liege Univ. (Belgium).
**THE EXTENDABLE REFRACTABLE MAST (ERM) THERMAL ANALYSIS: A HEAT RADIATION CASE STUDY VIA THE FINITE ELEMENT METHOD**
M. HOGGE, J. P. COBUT, J. FAGNOUL, E. STENNE, and P. M. LEONARD *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 227-235 Aug. 1986
Avail: NTIS HC A12/MF A01

A heat radiation finite element procedure was developed for the thermal analysis of an extendable retractable mast (ERM) for space shuttle solar arrays and antennas. Thermal loading of the mast is mainly by radiation, and such heat inputs are barely treated in a comprehensive way in finite element computer programs: radiative heat exchanges are defined in terms of surfaces whereas finite element models deal with nodal unknowns located at the boundary of the radiant areas. A procedure which enables an automatic translation of surface data into nodal inputs via specialized surface elements was developed and may be used along with standard codes for angle factors determination. The effectiveness of the method is demonstrated on ERM thermal models. ESA

**N87-16952#** Rome Univ. (Italy). Dipt. Aerospaziale.
**THERMOMECHANICAL CHARACTERISTICS OF DICHROIC SUBREFLECTORS**
C. ARDUINI, R. BARBONI, A. CASTELLANI, U. PONZI, and S. SGUBINI *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 255-260 Aug. 1986
Avail: NTIS HC A12/MF A01

Temperature, stress, and deformation aspects of Kevlar composite dichroic reflectors were studied. Criteria to guarantee that thermal displacements do not exceed any maximum value in the direction normal to the middle surface were derived. The skin of the sandwich was checked for thermal buckling to find a criterion for safe sizing. Different cases of Sun illumination and transient conditions were analyzed to determine the maximum gradient inside the structure. The structural analysis was carried out via finite elements. The type of finite element and the number of grid nodes were a compromise between the modeling requirements and the large number of cases which result from the structural concepts, design requirements, heating conditions, type of constraints, and materials properties. Thermostructural results are presented. ESA

**N87-17005#** Department of the Air Force, Washington, D.C.
**EXPANDABLE PULSE POWER SPACECRAFT RADIATOR Patent Application**
EDWARD T. MAHEFKEY, inventor (to Air Force) 18 Jun. 1986 23 p
(AD-D012498; US-PATENT-APPL-SN-875808) Avail: NTIS HC A02/MF A01 CSCL 20M

An expandable heat rejection system for radiating heat generated by a source of heat on a spacecraft or like vehicle is described and comprises a fluid heat exchange medium in operative heat exchange contact with the source for absorbing heat by evaporation of liquid phase of the medium, a thin flexible wall structure having an inlet and an outlet and defining a volume expandable and collapsible between preselected limits and defining an inner condensation surface and an outer heat radiating surface, a multiplicity of capillary grooves on the condensation surface for promoting condensation of vaporous medium and for facilitating flow of condensate along the condensation surface toward the outlet, and a pump circulating the medium through the system. GRA

**N87-17036*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**SUN SHIELD Patent**
ARTHUR M. FRANK, inventor (to NASA), SILVIO F. DERESPINIS, inventor (to NASA), and JOHN MOCKOVCIAK, JR., inventor (to NASA) 20 Jan. 1987 8 p Filed 12 Aug. 1985 Supersedes N86-20803 (24 - 11, p 1783)
(NASA-CASE-MSC-20162-1; US-PATENT-4,637,447; US-PATENT-APPL-SN-764805; US-PATENT-CLASS-160-265; US-PATENT-CLASS-160-23R; US-PATENT-CLASS-244-121; US-PATENT-CLASS-244-158R; US-PATENT-CLASS-135-903; US-PATENT-CLASS-296-100) Avail: US Patent and Trademark Office CSCL 13I

A shading device which is capable of compactly storing a flexible shade on a biased, window shade type spring roller is disclosed. It is controlled to deliver the shade selectively to either its operative shading or compact storage orientation.
Official Gazette of the US Patent and Trademark Office

**N87-18785*#** Hughes Aircraft Co., Torrance, Calif. Electron Dynamics Div.
**ADVANCED RADIATOR CONCEPTS UTILIZING HONEYCOMB PANEL HEAT PIPES (STAINLESS STEEL) Interim Technical Report**
G. L. FLEISCHMAN and H. J. TANZER Aug. 1985 78 p
(Contract NAS9-16581)
(NASA-CR-171977; NAS 1.26:171977; W-30746) Avail: NTIS HC A05/MF A01 CSCL 20D

The feasibility of fabricating and processing moderate temperature range heat pipes in a low mass honeycomb sandwich panel configuration for highly efficient radiator fins for the NASA space station was investigated. A variety of honeycomb panel facesheet and core-ribbon wick concepts were evaluated within constraints dictated by existing manufacturing technology and equipment. Concepts evaluated include: type of material, material and panel thicknesses, wick type and manufacturability, liquid and vapor communication among honeycomb cells, and liquid flow return from condenser to evaporator facesheet areas. In addition, the overall performance of the honeycomb panel heat pipe was evaluated analytically. Author

**N87-20353*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**LIQUID DROPLET RADIATOR DEVELOPMENT STATUS**

K. ALAN WHITE, III 1987 28 p Prepared for presentation at the 22nd Thermophysics Conference, Honolulu, Hawaii, 8-10 Jul. 1987; sponsored by AIAA

(NASA-TM-89852; E-3510; NAS 1.15:89852) Avail: NTIS HC A03/MF A01 CSCL 22B

Development of the Liquid Droplet Radiator (LDR) is described. Significant published results of previous investigators are presented, and work currently in progress is discussed. Several proposed LDR configurations are described, and the rectangular and triangular configurations currently of most interest are examined. Development of the droplet generator, collector, and auxiliary components are discussed. Radiative performance of a droplet sheet is considered, and experimental results are seen to be in very good agreement with analytical predictions. The collision of droplets in the droplet sheet, the charging of droplets by the space plasma, and the effect of atmospheric drag on the droplet sheet are shown to be of little consequence, or can be minimized by proper design. The LDR is seen to be less susceptible than conventional technology to the effects of micrometeoroids or hostile threats. The identification of working fluids which are stable in the orbital environments of interest is also made. Methods for reducing spacecraft contamination from an LDR to an acceptable level are discussed. Preliminary results of microgravity testing of the droplet generator are presented. Possible future NASA and Air Force missions enhanced or enabled by a LDR are also discussed. System studies indicate that the LDR is potentially less massive than heat pipe radiators. Planned microgravity testing aboard the Shuttle or space station is seen to be a logical next step in LDR development. Author

# 05

# ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS

Includes description of analytical techniques and models, trade studies of technologies, subsystems, support strategies, and experiments for internal and external environmental control and protection, life support systems, human factors, life sciences and safety.

**A87-13563*** National Aeronautics and Space Administration, Washington, D.C.

**BEYOND THE BIOSPHERE**

A. E. NICOGOSSIAN (NASA, Div. of Life Sciences; Uniformed Services University of Health Sciences, Washington, DC) and J. F. PARKER (Biotechnology, Inc., Annandale, VA) IN: Fundamentals of aerospace medicine . Philadelphia, PA, Lea and Febiger, 1985, p. 382-399. refs

The near-earth-space, planetary and interplanetary environments are described with emphasis on their biomedical significance. The characteristics of the microgravity field, low gravity and radiation conditions in earth orbit are described, noting the necessity of avoiding materials which can outgas toxic substances during long-term mission. Details of the atmospheres, global meteorology, and terrains of Venus, Mars, Jupiter, the Jovian satellites, and Saturn are reviewed. Finally, a brief discussion is provided of the life-support systems which will be required on interstellar voyages. M.S.K.

**A87-13709*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.

**FEASIBILITY OF EXPERT SYSTEMS TO ENHANCE SPACE STATION SUBSYSTEM CONTROLLERS**

J. T. MALIN and N. LANCE, JR. (NASA, Johnson Space Center, Houston, TX) IN: Space station automation; Proceedings of the Meeting, Cambridge, MA, September 17, 18, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1985, p. 28-34. refs

Results are described from a project to build a prototype expert system for automated fault isolation and correction of a regenerative CO2 removal device that is typical of functions of the air revitalization group in the Space Station environmental control and life support system (ECLSS). The software was developed using one of the powerful commercial knowledge engineering environments. The goal of the project was to evaluate the feasibility of using a software development environment to rapidly design, construct, test, and change expert system software. The use of expert systems to enhance automatic controllers and the use of information on device design and on device troubleshooting and repair procedures in developing expert systems are discussed. Author

**A87-15815#**

**QUANTIFYING HUMAN PERFORMANCE IN SPACE OPERATIONS**

D. L. AKIN (MIT, Cambridge, MA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 18 p. refs

(IAF PAPER 86-24)

Results of several experimental programs aimed at quantifying the productivities of humans and machines in the space environment, both simulated and actual, are reviewed. Through neutral buoyancy simulation and space flight verification, it has been shown that humans are highly productive in EVA structural assembly and in many of those generic tasks required for any purposeful activity in the EVA field. Further neutral buoyancy research has started to document the capabilities of humans in the control of teleoperators, specifically in tasks requiring both vehicle mobility and dexterous manipulation. V.L.

**A87-15826#**

**INTERIOR DESIGN OF THE U.S. SPACE STATION HABITATION MODULES**

D. C. WENSLEY (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 18 p.

(IAF PAPER 86-39)

This paper describes design concepts for the habitation modules of the Space Station. A flexible interior architecture features modularized equipment compartments that permit access for maintenance and in-orbit reconfiguration as functional requirements change. The overall interior arrangement is presented with emphasis on crew quarters, operations and maintenance work stations, galley provisions, health maintenance facilities and subsystem equipment compartments. Electrical and fluid utilities are shown. Design features to enhance crew comfort and safety are described as well as functional and design relationships with the European and Japanese modules and the U.S. laboratories. Author

**A87-15836*#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany).

**ASSESSMENT OF SPACE STATION DESIGN AND OPERATION THROUGH BIOASTRONAUTICS**

K. E. KLEIN, H. M. WEGMANN (DFVLR, Institut fuer Flugmedizin, Cologne, West Germany), and B. J. BLUTH (NASA, Office of Space Station, Washington, DC) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p. refs

(IAF PAPER 86-54)

The main elements which affect human well-being and productivity during a mission on the Space Station are reviewed. These include: the physical environment, the nature of operations the crew is required to perform, man's physiological response to

microgravity, and the psychological and social conditions. The individual components of each of these elements are presented, and special design and support needs are identified. Particular attention is given to noise pollution, ionizing radiation, and behavioral factors. K.K.

**A87-15838#**
**HUMAN FACTORS FOR SPACE STATION**
J. W. BROWN and N. E. BROWN IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 10 p. refs
(IAF PAPER 86-59A)
The role of human factors in the design of the Space Station is considered. Sufficient space is required to provide day-to-day living and working areas for the crew members, and room for Station and crew support equipments. Crew safety and rescue which involve proper man/system interface, adequate provisions, in-orbit rescue capabilities, crew health maintenance, and crew training are examined. The maintenance of Space Station operations and the use of automatic systems and telerobotics in the Station are discussed. The in-space and on-ground maintenance and servicing of the Space Station are studied. I.F.

**A87-15845#**
**SPACE STATION ATMOSPHERIC MONITORING SYSTEMS**
C. BUONI, R. COUTANT, R. BARNES, and L. SLIVON (Battelle Columbus Laboratories, OH) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p.
(IAF PAPER 86-66)
A technology assessment study on atmospheric monitoring systems was performed to identify the monitoring requirements of the systems for measuring the atmospheric contaminants of the Space Station, assess the sampling and analytical technology, and identify the requirements of additional research and technological developments. Based on the analysis, the principal candidates recommended for the Space Station initial operational capability were: (1) long-path Fourier transform IR for rapid detection of high-risk contamination incidents and (2) gas chromatography/mass spectrometry utilizing mass selective detector (or ion-trap) technologies for detailed monitoring of extended crew exposure to low level (ppbv) contamination. I.S.

**A87-16063#**
**NEUROHUMORAL MECHANISM OF SPACE MOTION SICKNESS**
A. I. GRIGOREV, A. D. EGOROV, and I. A. NICHIPORUK (Institut Mediko-Biologicheskikh Problem, Moscow, USSR) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. refs
(IAF PAPER 86-384)
This paper reviews existing hypotheses concerning the mechanisms of adaptation of the vestibular apparatus and related somatosensory systems to microgravity, with reference to flight data. Based on the theoretical concepts and experimental data accumulated in space flights, a conceptual model of the development of a functional system responsible for the termination of vestibular dysfunction and space motion sickness manifestations is presented. It is also shown that changes in the hormonal status during motion sickness induced by vestibular stimulation provide evidence that endocrine regulation of certain functions can be involved in adaptive responses. Author

**A87-16064#**
**THE EYE-MOVEMENTS DURING SLEEP - MODELLING OF THE SPACELAB-1 RESULTS**
P. A. DEQUAE and O. J. QUADENS (Antwerpen, Rijksuniversitair Centrum, Antwerp, Belgium) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. refs
(IAF PAPER 86-386)
Analysis of the serial dependency of the time intervals between the rapid eye movements (REMs) during sleep has shown that consecutive intervals tend to be of similar duration (long after long, short after short), while there is a dynamical interaction between the long and the short intervals. The Spacelab-1 experiment has confirmed the hypothesis drawn from previous studies of Petre-Quadeus and De Lee (1970) that the REMs consist of two types of events, and that the consecutive time intervals are not a random phenomenon. The process can be described by means of a finite - semi-Markov chain model of the 1st order. Entropy ratios calculated from the simulated REM process evidenced an increase in serial dependency during the first night in space and after early return to normal gravity. Author

**A87-16065#**
**VESTIBULAR FACTORS INFLUENCING THE BIOMEDICAL SUPPORT OF HUMANS IN SPACE**
B. K. LICHTENBERG (Payload Systems, Inc., Wellesley, MA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 6 p.
(IAF PAPER 86-389)
The medical support needed to counter the long-term and short-term effects of weightlessness on the vestibular system are described. The vestibular system consists of semicircular canals and otolith organs, and provides orientation ability, to stabilize the eyes during head and body motion, and to help control posture and locomotion. The role of head motions in inducing space motion sickness is discussed. The otolith tilt-translation reinterpretation hypothesis which occurs upon reentry to the earth's atmosphere is examined. The use of artificial gravity to offset long-term effects on the vestibular system is considered. I.F.

**A87-16066#**
**CENTRAL AND REGIONAL HEMODYNAMICS IN PROLONGED SPACE FLIGHTS**
O. G. GAZENKO, E. B. SHULZHENKO, V. F. TURCHANINOVA, and A. D. EGOROV (Institut Mediko-Biologicheskikh Problem, Moscow, USSR) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p. refs
(IAF PAPER 86-390)
Central and regional circulations at rest and during provocative tests on short-term (7 days) and long-term (65-237 days) space flights are examined. Tetrapolar rheography was utilized to measure the circulations. The data reveal that rest stroke volume, cardiac output, and heart rate decrease during short-term flights, remain unchanged during long-term flights, and increase during long-term flights following exercise. It is noted that regional circulation variations are induced by a rearrangement of the total hemodynamics of the body in microgravity. I.F.

**A87-16067#**
**CORRELATION OF MACRO AND MICRO CARDIOVASCULAR FUNCTION DURING WEIGHTLESSNESS AND SIMULATED WEIGHTLESSNESS**
P. M. HUTCHINS, T. H. MARSHBURN, T. L. SMITH, S. W. OSBORNE, C. D. LYNCH (Wake Forest University, Medical Center, Winston-Salem, NC) et al. IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 6 p. refs
(IAF PAPER 86-391)
An animal model is developed in which one can correlate microvascular and systemic cardiovascular function. The microcirculatory preparation consists of a lightweight, thermoneutral chamber implanted around intact skeletal muscle on the back of a rat. Using this technique, the preformed microvasculature of the cutaneous maximus muscle may be observed in the conscious, unanesthetized animal. Microcirculatory variables which may be obtained include venular and arteriolar numbers, lengths and diameters, ssingle vessel flow velocities, vasomotion, capillary hematocrit anastomoses and orders of branching. Systemic hemodynamic monitoring of cardiac output by electromagnetic flowmetry, and arterial and venous pressures allows correlation of macro- and microcirculatory changes at the same time, inthe same animal. Author

**A87-16068*#** State Univ. of New York, Buffalo.
**BIOMEDICAL SUPPORT OF MAN IN SPACE**
D. R. PENDERGAST, A. J. OLSZOWKA, M. A. ROKITKA, and L. E. FARHI (New York, State University, Buffalo) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. refs
(Contract NAS9-16042)
(IAF PAPER 86-393)

The effects of G and/or exercise on cardiopulmonary adjustments to stresses are studied. The control of the cardiopulmonary system is examined using simulated microgravity (recumbency, immersion, lower body positive pressure, and 6-deg head-down tilt) and increased acceleration. It is observed that at rest and during exercise in simulated zero-6 environments, the stroke volume and cardiac output are initially increased and then (after prolonged exposure) return to prezero-G levels. Cardiovascular responses to increased gravity (1, 2, and 3 G) at rest and during exercise are analyzed; a decrease in plasma volume resulting in decreases in stroke volume and cardiac output, and an increase in heart rate are detected. I.F.

**A87-16069*#** National Aeronautics and Space Administration, Washington, D.C.
**ASSESSMENT OF THE EFFICACY OF MEDICAL COUNTERMEASURES IN SPACE FLIGHT**
A. NICOGOSSIAN, F. SULZMAN (NASA, Life Sciences Div., Washington, DC), M. RADTKE (Management and Technical Services Co., Washington, DC), and M. BUNGO (NASA, Johnson Space Center, Houston, TX) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 5 p.
(IAF PAPER 86-394)

Changes in body fluids, electrolytes and muscle mass are manifestations of adaptation to space flight and readaptation to the 1-g environment. The purpose of this paper is to review the current knowledge of biomedical responses to short- and long-duration space missions and to assess the efficacy of countermeasures to 1-g deconditioning. Exercise protocols, fluid hydration, dietary and potential pharmacologic measures are evaluated, and directions for future research activities are recommended. Author

**A87-16070*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**ANIMALS IN BIOMEDICAL SPACE RESEARCH**
R. W. PHILLIPS (NASA, Johnson Space Center, Houston, TX; Colorado State University, Fort Collins) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 4 p.
(IAF PAPER 86-395)

Rat and squirrel monkeys experiments have been planned in concert with human experiments to help answer fundamental questions concerning the effect of weightlessness on mammalism function. For the most part, these experiments focus on identified changes noted in humans during space flight. Utilizing space laboratory facilities, manipulative experiments can be completed while animals are still in orbit. Other experiments are designed to study changes in gravity receptor structure and function and the effect of weightlessness on early vertibrate development. Following these preliminary animal experiments on Spacelab Shuttle flights, longer term programs of animal investigation will be conducted on Space Station. Author

**A87-16071*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**SPACE STATION HABITABILITY RESEARCH**
Y. A. CLEARWATER (NASA, Ames Research Center, Moffett Field, CA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p. refs
(IAF PAPER 86-397)

The purpose and scope of the Habitability Research Group within the Space Human Factors Office at the NASA/Ames Research Cente is described. Both near-term and long-term research objectives in the space human factors program pertaining to the U.S. manned Space Station are introduced. The concept of habitability and its relevancy to the U.S. space program is defined within a historical context. The relationship of habitability research to the optimization of environmental and operational determinants of productivity is discussed. Ongoing habitability research efforts pertaining to living and working on the Space Station are described. Author

**A87-16075#**
**SPACE STATION HABITABILITY STUDY - THE RELATION BETWEEN VOLUMES, SHAPES AND COLOURS, INSIDE THE SPACE STATION AND HUMAN BEHAVIOUR**
D. B. ARCHITECT (Futuro, Florence, Italy) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. refs
(IAF PAPER 86-403)

**A87-16083#**
**RISK ANALYSIS METHODS FOR SPACE STATION DESIGN AND DEVELOPMENT**
C. R. HADLOCK and P. E. GLASER (Arthur D. Little, Inc., Cambridge, MA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 12 p. refs
(IAF PAPER 86-424)

The use of risk analysis frameworks for evaluating Space Station design is discussed. Sources of risk and safety goals are identified, and risk analysis methodologies are summarized. Event trees and fault trees are used to obtain a detailed understanding of the logical possibilities for system behavior in light of potential hazards and to estimate the likelihood of different modes of undesirable behavior or failure. It is noted that the application of probabilistic risk analysis (PRA) methods for the purpose of safety evaluation should not be carried out divorced from the reliability, maintainability, and availabilty analyses that are currently being carried out within the Space Station program. K.K.

**A87-18162**
**POST-OPERATIONAL DISPOSAL OF SPACE NUCLEAR REACTORS**
J. A. ANGELO, JR. (Florida Institute of Technology, Melbourne) and D. BUDEN (Science Applications International Corp., Albuquerque, NM) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1974-1979. refs

Space nuclear reactors will play a major role in tomorrow's U.S. space program. One of the most important issues facing future applications of nuclear energy in space, for either power or propulsion, is the overall question of aerospace nuclear safety. The majority of aerospace nuclear safety efforts to date have focused on the safety aspects of pre-launch, launch, and initial reactor start up activities. With the exception of the concept of a 'safe nuclear orbit', little emphasis has been placed on the postoperational disposal of a space nuclear reactor. This paper introduces potential technical strategies for the safe, acceptable postoperational disposal of future, high power level space nuclear reactors that could be used throughout cislunar space in the 21st Century. The space technology infrastructure needed to support various postoperational disposal concepts is discussed as well as potential extraterrestrial disposal locations. Author

**A87-18397*** National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, Fla.
**OPERATIONAL MEDICINE IN SPACE STATION ERA**
S. FURUKAWA (NASA, Kennedy Space Center; McDonnell Douglas Technical Services, Co., Cocoa Beach, FL) and P. BUCHANAN (NASA, Kennedy Space Center, Cocoa Beach, FL) IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 1541-1551. refs

Medical considerations for long duration manned space missions are examined. The requirements and hardware for medical operations on the Space Station are diagrammatically presented.

The physiological and psychological changes that have been observed during space flights are discussed. Crew health maintenance and medical care in the Space Station environment require earth-based and in flight continuity. It is also necessary to identify the appropriate zero-G therapeutic methods for treating a patient. Techniques for transferring patients in orbit and to earth are studied. Considerations are given to control and life support systems and data management for medical operations. I.F.

**A87-19066*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**CARDIOVASCULAR RESEARCH IN SPACE - CONSIDERATIONS FOR THE DESIGN OF THE HUMAN RESEARCH FACILITY OF THE UNITED STATES SPACE STATION**
J. B. CHARLES and M. W. BUNGO (NASA, Johnson Space Center, Houston, TX) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 57, Oct. 1986, p. 1000-1005. refs

The design of the Space Station's Human Research Facility for the collection of information on the long-time physiological adjustments of humans to space is described. The Space Life Sciences-1 mission will carry a rack-mounted echocardiograph for cardiac imaging, a mass spectrometer for cardiac output and respiratory function assessments at rest and during exercise, and a device to stimulate the carotid sinus baroreceptors and measure the resulting changes in heart rate. I.S.

**A87-21982#**
**CONVERSION OF DEPTH-DOSE DISTRIBUTIONS FROM SLAB TO SPHERICAL GEOMETRIES FOR SPACE-SHIELDING APPLICATIONS**
STEPHEN M. SELTZER (NBS, Gaithersburg, MD) (IEEE, DNA, Sandia National Laboratories, and NASA, 1986 Annual Conference on Nuclear and Space Radiation Effects, 23rd, Providence, RI, July 21-23, 1986) IEEE Transactions on Nuclear Science (ISSN 0018-9499), vol. NS-33, Dec. 1986, pt. 1, p. 1292-1297. Navy-DOE-supported research. refs

An approximate procedure has been developed to transform depth-dose distributions in simple slab targets so as to obtain the spatial distribution of dose in spherical target configurations for space-shielding applications. Emphasis is placed on the determination of electron and bremsstrahlung dose, which would otherwise require more costly three-dimensional Monte Carlo calculations. For the electron-bremsstrahlung problems tested, results from the procedure require only a fraction of the computer time and are found to agree to within 10-20 percent as compared to direct, three-dimensional Monte Carlo calculations. Author

**N87-12060*#** Ionics Research, Inc., Houston, Tex.
**ORGANICS IN WATER CONTAMINATION ANALYZER, PHASE 1 Final Report**
2 Jun. 1986 14 p
(Contract NAS9-17536)
(NASA-CR-179901; NAS 1.26:179901) Avail: NTIS HC A02/MF A01 CSCL 13B

The requirements which would result in identifying the components of an automatic analytical system for the analysis of specific organic compounds in the space station potable water supply are defined. The gas chromatographic system for such an analysis is limited to commercially available off-the-shelf hardware and includes the sample inlet, an ionization detector, capillary columns as well as computerized compound identification. The sampling system will be a special variation of the purge and trap Tenax mode using six-port valves and a 500 microliter water sample. Capillary columns used for the separating of contaminants will be bonded phase fused silica with a silicone stationary phase. Two detectors can be used: photoionization and far ultraviolet, since they are sensitive and compatible with capillary columns. A computer system evaluation and program with the principle of compound identification based on the retention index is presented. Author

**N87-12166*#** Lockheed Engineering and Management Services Co., Inc., Houston, Tex.
**THE SPACE STATION: HUMAN FACTORS AND PRODUCTIVITY**
D. J. GILLAN, M. J. BURNS, C. L. NICODEMUS, and R. L. SMITH 1986 9 p
(Contract NAS9-15800)
(NASA-CR-179905; NAS 1.26:179905) Avail: NTIS HC A02/MF A01 CSCL 05H

Human factor researchers and engineers are making inputs into the early stages of the design of the Space Station to improve both the quality of life and work on-orbit. Effective integration of the human factors information related to various Intravehicular Activity (IVA), Extravehicular Activity (EVA), and teletobotics systems during the Space Station design will result in increased productivity, increased flexibility of the Space Stations systems, lower cost of operations, improved reliability, and increased safety for the crew onboard the Space Station. The major features of productivity examined include the cognitive and physical effort involved in work, the accuracy of worker output and ability to maintain performance at a high level of accuracy, the speed and temporal efficiency with which a worker performs, crewmember satisfaction with their work environment, and the relation between performance and cost. B.G.

**N87-13166*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**THE ECOLOGY OF MICROORGANISMS IN A SMALL CLOSED SYSTEM: POTENTIAL BENEFITS AND PROBLEMS FOR SPACE STATION**
E. B. RODGERS Oct. 1986 61 p
(NASA-TM-86563; NAS 1.15:86563) Avail: NTIS HC A04/MF A01 CSCL 06K

The inevitble presence on the space station of microorganisms associated with crew members and their environment will have the potential for both benefits and a range of problems including illness and corrosion of materials. This report reviews the literature presenting information about microorganisms pertinent to Environmental Control and Life Support (ECLS) on the space station. The perspective of the report is ecological, viewing the space station as an ecosystem in which biological relationships are affected by factors such as zero gravity and by closure of a small volume of space. Potential sites and activities of microorganisms on the space station and their environmental limits, microbial standards for the space station, monitoring and control methods, effects of space factors on microorganisms, and extraterrestrial contamination are discussed. Author

**N87-16012*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**SCIENCE AND TECHNOLOGY ISSUES IN SPACECRAFT FIRE SAFETY**
ROBERT FRIEDMAN and KURT R. SACKSTEDER Jan. 1987 29 p Presented at the 25th Aerospace Sciences Meeting, Reno, Nev., 12-15 Jan. 1987; sponsored by AIAA
(NASA-TM-88933; E-3349; NAS 1.15:88933; AIAA-87-0467) Avail: NTIS HC A03/MF A01 CSCL 22B

The space station, a permanently-inhabited orbiting laboratory, places new demands on spacecraft fire safety. Long-duration missions may call for more-constrained fire controls, but the accessibility of the space station to a variety of users may call for less-restrictive measures. This paper discusses fire safety issues through a review of the state of the art and a presentation of key findings from a recent NASA Lewis Research Center Workshop. The subjects covered are the fundamental science of low-gravity combustion and the technology advances in fire detection, extinguishment, materials assessment, and atmosphere selection. Key concerns are for the adoption of a fire-safe atmosphere and the substitution for the effective but toxic extinguishant, halon 1301. The fire safety studies and reviews provide several recommendations for further action. One is the expanded research in combustion, sensors, and materials in the low-gravity environment of space. Another is the development of generalized

fire-safety standards for spacecraft through cooperative endeavors with aerospace and outside Government and industry sources.
Author

**N87-16865*#** Lockheed Missiles and Space Co., Sunnyvale, Calif.
**SPACE STATION HUMAN PRODUCTIVITY STUDY. VOLUME 4: ISSUES Final Report**
Nov. 1985 178 p
(Contract NAS9-17272)
(NASA-CR-171963; NAS 1.26:171963; LMSC-F060784/4-VOL-4; DR-SE-1093T-VOL-4) Avail: NTIS HC A09/MF A01 CSCL 22B

The 305 'Issues contained represent topics recommended for study in order to develop requirements in support of space station crew performance/productivity. The overall subject matter, space station elements affecting crew productivity, was organized into a coded subelement listing, which is included for the reader's reference. Each issue is numbered according to the 5-digit topical coding scheme. The requirements column on each Issue page shows a cross-reference to the unresolved requirement statement(s). Because topical overlaps were frequently encountered, many initial Issues were consolidated. Apparent gaps, therefore, may be accounted for by an Issue described within a related subelement. A glossary of abbreviations used throughout the study documentation is also included. Author

**N87-16866*#** Lockheed Missiles and Space Co., Sunnyvale, Calif.
**SPACE STATION HUMAN PRODUCTIVITY STUDY. VOLUME 5: MANAGEMENT PLANS Final Report**
Nov. 1985 517 p
(Contract NAS9-17272)
(NASA-CR-171964; NAS 1.26:171964; LMSC-F060784/5-VOL-5; DR-SE-1093T-VOL-5) Avail: NTIS HC A22/MF A01 CSCL 22B

The 67 Management Plans represent recommended study approaches for resolving 108 of the 305 Issues which were identified. Each study Management Plan is prepared in three formats: Management Plan Overview (lists the subsumed Issues, study background, and related overview information); Study Plan (details the study approach by tasks, lists special needs, and describes expected study products); Schedule-Task Flow (provides a time-lined schedule for the study tasks and resource requirements). The Management Relationships Matrix, included in this volume, shows the data input-output relationships among all recommended studies. A listing is also included which cross-references the unresolved requirements to Issues to management plans. A glossary of all abbreviations utilized is provided. Author

**N87-16868*#** Lockheed Missiles and Space Co., Sunnyvale, Calif.
**SPACE STATION HUMAN PRODUCTIVITY STUDY. VOLUME 2: EXECUTIVE SUMMARY AND ORAL REVIEW PRESENTATION Final Report**
Nov. 1985 81 p
(Contract NAS9-17272)
(NASA-CR-171962; NAS 1.26:171962; LMSC-F060784/2-VOL-2; DR-SE-1093T-VOL-2) Avail: NTIS HC A05/MF A01 CSCL 22B

Definition of design/operations requirements for support of human productivity, identification of problem areas lacking data for requirements definition, generation of management plans for conduct of studies to acquire needed data for timely space station program impact, and correlation of all issue study management plans with space station progam milestone need dates were addressed. B.G.

**N87-16869*#** Lockheed Missiles and Space Co., Sunnyvale, Calif.
**SPACE STATION HUMAN PRODUCTIVITY STUDY, VOLUME 1 Final Report**
Nov. 1985 71 p
(Contract NAS9-17272)
(NASA-CR-171961; NAS 1.26:171961; LMSC-F060784/1-VOL-1)
Avail: NTIS HC A04/MF A01 CSCL 22B

The primary goal was to develop design and operations requirements for direct support of intra-vehicular activity (IVA) crew performance and productivity. It was recognized that much work had already been accomplished which provided sufficient data for the definition of the desired requirements. It was necessary, therefore, to assess the status of such data to extract definable requirements, and then to define the remaining study needs. The explicit objectives of the study were to: review existing data to identify potential problems of space station crew productivity and to define requirements for support of productivity insofar as they could be justified by current information; identify those areas that lack adequate data; and prepare plans for managing studies to develop the lacking data, so that results can be input to the space station program in a timely manner. Author

**N87-17749*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**CELSS AND REGENERATIVE LIFE SUPPORT FOR MANNED MISSIONS TO MARS**
R. D. MCELROY *In* NASA. Marshall Space Flight Center Manned Mars Missions. Working Group Papers, Volume 1, Section 1-4 p 363-376 May 1986
Avail: NTIS HC A22/MF A01 CSCL 22A

In the mid 1990's, the space station will become a point from which inter-planetary vehicles can be launched. The practicalities of a manned Mars mission are now being studied, along with some newer concepts for human life support. Specifically, the use of organisms such as plants and algae as the basis for life support systems is now being actively considered. A Controlled Ecological Life Support System (CELSS) is composed of several facilities: (1) to grow photosynthetic plants or algae which will produce food, oxygen and potable water, and remove carbon dioxide exhaled by a crew; (2) to process biomass into food; (3) to oxidize organic wastes into CO2; and (4) to maintain system operation and stability. Such a system, when compared to using materials stored at launch, may have distinct weight and cost advantages, depending upon crew size and mission duration, as well as psychological benefits for the crew. The use of the system during transit, as well as in establishing a re-visitable surface camp, will increase the attractiveness of the CELSS concept for life support on interplanetary missions. Author

**N87-17797*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**MANNED MARS MISSION ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM**
UWE HUETER *In its* Manned Mars Mission. Working Group Papers, V. 2, Sect. 5, App. p 901-909 May 1986
Avail: NTIS HC A24/MF A01 CSCL 06K

A specific design is not presented, but the general philosophy regarding potential Environmental Control/Life Support System (ECLSS) requirements, concepts, issues, and technology needs are discussed. The focus is on a manned Mars mission occurring in the late 1990's. Discussions on the Trans-Mars Vehicle, the Mars Excursion Module (MEM), and a Martian base facility are covered. The functions, performance requirements, and design loads of a typical ECLSS are listed, and the issues and technology briefly discussed. Several ECLSS concepts and options are identified, and comparative weights and volumes are provided for these. Several aspects of the space station ECLSS are contrasted with the Mars element ECLSS. Author

**N87-18400*#** Wyle Labs., Inc., Arlington, Va.
**SPACE STATION INTERIOR NOISE ANALYSIS PROGRAM Final Report**
E. STUSNICK and M. BURN Feb. 1987 67 p
(Contract NAS1-18026)
(NASA-CR-178190; NAS 1.26:178190; WR-86-13) Avail: NTIS HC A04/MF A01 CSCL 20A

Documentation is provided for a microcomputer program which was developed to evaluate the effect of the vibroacoustic environment on speech communication inside a space station. The program, entitled Space Station Interior Noise Analysis Program (SSINAP), combines a Statistical Energy Analysis (SEA) prediction of sound and vibration levels within the space station with a speech intelligibility model based on the Modulation Transfer Function and the Speech Transmission Index (MTF/STI). The SEA model provides an effective analysis tool for predicting the acoustic environment based on proposed space station design. The MTF/STI model provides a method for evaluating speech communication in the relatively reverberant and potentially noisy environments that are likely to occur in space stations. The combinations of these two models provides a powerful analysis tool for optimizing the acoustic design of space stations from the point of view of speech communications. The mathematical algorithms used in SSINAP are presented to implement the SEA and MTF/STI models. An appendix provides an explanation of the operation of the program along with details of the program structure and code. Author

**N87-18983*#** Texas A&M Univ., College Station. Regenerative Concepts Group.
**CONCEPTUAL DESIGN FOR A FOOD PRODUCTION, WATER AND WASTE PROCESSING, AND GAS REGENERATION MODULE Semiannual Progress Report**
O. W. NICKS 15 Nov. 1986 97 p
(Contract NAG9-161)
(NASA-CR-180208; NAS 1.26:180208; SRC-5494-1) Avail: NTIS HC A05/MF A01 CSCL 06K

During the first six month period, the RECON (Regenerative Concepts Group) team collected reference material, made visits to consult with other researchers, and invited distinguished visitors to speak on the status of closed life support activities. A decision was made to develop the data base and modeling such that artificial intelligence (AI) methods could be used to manipulate data and examine concept alternatives. Six discrete tasks and a project schedule were outlined for the first year. The first two tasks have been essentially completed and have resulted in a sample set of assumptions for general use in defining candidate systems and for the specification of closed system characteristics. To model a closed environment, decisions were necessary to establish the amounts of food, air, water and waste products. Although recognized that data would eventually be normalized on the basis of a single human, the amount of data in existence for four person crews led to the decision to use this as a baseline. Information on existing concepts was collected from NASA sources, from industry, and libraries. Concept modeling was begun, hardware and software obtained, technical tasks identified and experimental work initiated. Author

**N87-20342*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**FIRE SAFETY CONCERNS IN SPACE OPERATIONS**
ROBERT FRIEDMAN 1987 13 p Prepared for presentation at the Joint Army-Navy-NASA-Air Force (JANNAF) Safety and Environmental Protection Subcommittee Meeting, Cleveland, Ohio, 4-7 May 1987
(NASA-TM-89848; E-3511; NAS 1.15:89848) Avail: NTIS HC A02/MF A01 CSCL 22A

This paper reviews the state-of-the-art in fire control techniques and identifies important issues for continuing research, technology, and standards. For the future permanent orbiting facility, the space station, fire prevention and control calls for not only more stringent fire safety due to the long-term and complex missions, but also for simplified and flexible safety rules to accommodate the variety of users. Future research must address a better understanding of the microgravity space environment as it influences fire propagation and extinction and the application of the technology of fire detection, extinguishment, and material assessment. Spacecraft fire safety should also consider the adaptation of methods and concepts derived from aircraft and undersea experience. Author

# 06

# DYNAMICS AND CONTROLS

Includes descriptions of analytical techniques and computer codes, trade studies, requirements and descriptions of orbit maintenance systems, rigid and flexible body attitude sensing systems and controls such as momentum wheels and/or propulsive schemes.

**A87-12139**
**STABILIZATION OF A CLASS OF HYBRID SYSTEMS ARISING IN FLEXIBLE SPACECRAFT**
S. K. BISWAS (Ottawa, University, Canada) and N. U. AHMED Journal of Optimization Theory and Applications (ISSN 0022-3239), vol. 50, July 1986, p. 83-108. refs
(Contract NSERC-A-7109)

Consideration is given to the problem of rigorous modeling of flexible spacecraft and their stabilization. It is shown that the dynamics of the flexible spacecraft can be described by a coupled system of ordinary differential equations and partial differential equations (hybrid system). Liapunov's approach is used to prove the stabilizability of the system. Simple feedback controls are suggested for stabilization of flexible spacecraft. Author

**A87-13317*** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**FAILURE-ACCOMMODATING CONTROL OF LARGE FLEXIBLE SPACECRAFT**
S. M. JOSHI (NASA, Langley Research Center, Hampton, VA) IN: 1986 American Control Conference, 5th, Seattle, WA, June 18-20, 1986, Proceedings. Volume 1 . New York, Institute of Electrical and Electronics Engineers, 1986, p. 156-161. refs

This paper considers the problem of designing failure-accommodating controllers for large flexible spacecraft when there are sector-type nonlinearities in the loops. It is proved that an LQG-type controller can be made failure tolerant by inserting appropriate gains in the actuator paths and state estimator residual paths. For the state feedback case, when the actuators are saturating type, it is proved that there exists a finite region of attraction, which is invariant in the presence of these gains. Another class of controllers, which employs collocated sensors and actuators is presented, and is shown to have excellent failure-accommodation properties in addition to its robustness properties. Author

**A87-13392**
**A LABORATORY EXPERIMENT IN CONTROL/STRUCTURE INTERACTION**
J. A. BOSSI and J.-W. TSOU (Washington, University, Seattle) IN: 1986 American Control Conference, 5th, Seattle, WA, June 18-20, 1986, Proceedings. Volume 2 . New York, Institute of Electrical and Electronics Engineers, 1986, p. 1034-1038. Research supported by Boeing Aerospace Co.

A laboratory simulation having the characteristics of a flexible spacecraft (i.e. multiple, coupled rigid-body and flexible modes) is described. Initial test results utilizing the simulator as a test bed for multivariable control law designs are presented. Author

**A87-13393**
**SLEW MANEUVER CONTROL OF THE SPACECRAFT CONTROL LABORATORY EXPERIMENT (SCOLE)**
Y. P. KAKAD (North Carolina, University, Charlotte) IN: 1986 American Control Conference, 5th, Seattle, WA, June 18-20, 1986, Proceedings. Volume 2 . New York, Institute of Electrical and Electronics Engineers, 1986, p. 1039-1044. refs

In this paper, the dynamics and control of the NASA-Spacecraft Control Laboratory Experiment (SCOLE) test article slew maneuver are developed. The slew maneuver is specified about any arbitrary axis of the spacecraft, and it is considered that the spacecraft undergoes nonlinear rigid-body motion and linear elastic motion.
Author

**A87-13395*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.
**DESIGN OF ROBUST FAILURE DETECTION FILTERS**
A. M. SAN MARTIN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) and W. E. VANDER VELDE (MIT, Cambridge, MA) IN: 1986 American Control Conference, 5th, Seattle, WA, June 18-20, 1986, Proceedings, Volume 2 . New York, Institute of Electrical and Electronics Engineers, 1986, p. 1052-1059. refs
(Contract NAG1-126)

An essential aspect of the design of control systems for large, flexible spacecraft is fault tolerance. Because it is anticipated that a large number of sensors and actuators will be required to realize good control over these assemblies, the detection and isolation of component failures cannot be based on direct comparisons among replicated components. Instead, the notion of 'analytic redundancy' must be employed for the FDI function. Unfortunately this makes the FDI function sensitive to modeling errors which are certain to exist in the large space structure problem due to model truncation and parameter uncertainty. This paper addresses the robustness to model error of one method of FDI residual generation - the failure detection filter. Initial designs were found to be extremely sensitive to modeling error. The sources of this sensitivity are analyzed and modifications to the design are suggested. The improved filter is shown to have much better visibility of the failure signatures relative to the background due to modeling error.
Author

**A87-15450**
**FLEXIBILITY CONTROL OF SOLAR ARRAYS BASED ON STATE ESTIMATION BY KALMAN FILTERING**
T. FUKUDA, Y. KURIBAYASHI, H. HOSOKAI (Tokyo Science University, Japan), and N. YAJIMA (Ministry of International Trade and Industry, Mechanical Engineering Laboratory, Sakura, Japan) IN: Theoretical and applied mechanics. Volume 34 - Proceedings of the Thirty-fourth Japan National Congress for Applied Mechanics, Tokyo, Japan, December 11, 12, 1984 . Tokyo/New York, University of Tokyo Press/Columbia University Press, 1986, p. 405-411. refs

The problem dealt with here is how to estimate and control the vibrational modes of flexible booms of solar arrays even in large angle attitude maneuvers. The boom is controlled as a distributed parameter system, the dynamics of which is developed in the manner of the unconstrained mode. Differential solar cell sensors are used to measure vibrations of the boom, but the sensor outputs are contaminated by noises. Therefore, the Kalman filtering method is employed to estimate states based on the dynamics in the above. Then all estimated states are fed back to control the whole system, and an optimal control strategy is employed so that the control performance can be improved.
Author

**A87-15931*#** Massachusetts Inst. of Tech., Cambridge.
**A PROCEDURE FOR CALCULATING THE DAMPING IN MULTI-ELEMENT SPACE STRUCTURES**
E. F. CRAWLEY and K. J. ODONNELL (MIT, Cambridge, MA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 10 p. refs
(Contract NAGW-21)
(IAF PAPER 86-203)

A procedure for analyzing the damping in a multielement space structure connected by joints is described, in which distributed material damping and discrete nonlinear joint properties are incorporated into a linear analysis. The procedure involves four steps: (1) creation of a linear undamped finite element model; (2) experimental measurements of the transient response of a truss member in free fall tests to obtain material damping properties; with these properties incorporated into a linear damped finite element model of the structure; (3) the identification of the nonlinear joint properties using the force-state mapping technique; and (4) linearization of the identified nonlinear components, which are then incorporated into the linear damped model to create the linearized damped finite element model.
I.S.

**A87-15932#**
**IMPROVING THE ACTIVE VIBRATIONAL CONTROL OF LARGE SPACE STRUCTURES THROUGH STRUCTURAL MODIFICATIONS**
F. E. EASTEP (Dayton, University, OH), N. S. KHOT (USAF, Wright Aeronautical Laboratories, Wright Patterson AFB, OH), and R. V. GRANDHI (Wright State University, Dayton, OH) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. refs
(IAF PAPER 86-204)

Structural and control system design methods for large space structures are presently integrated in order to reduce structural response to the disturbances encountered. The design scheme formulation is obtained by means of the structural modification of a nominal finite element model that is optimally controlled by a linear regulator, in order to increase the active modal damping factor beyond that of the nominal structure. Because an optimal active control method is employed, the sensitivity of the Riccati matrix to structural modifications is obtained. The algorithm's application is illustrated by structural modification of a nominal model with different constraints on the closed loop eigenvalues.
O.C.

**A87-15959#**
**INSTABILITY OF ROTATING BLADES IN SPACE**
M. NATORI (Tokyo, University, Japan) and S. NEMAT-NASSER (California, University, La Jolla) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. refs
(IAF PAPER 86-242)

Basic aspects of instability of a flexible rotating blade due to solar radiation pressure are studied as a first step toward an instability study of future bladed space vehicles. A fundamental set of equations for coupled flap-lag-pitch motion of a very flexible rotation blade is presented, including the coupling and nonlinear terms associated with the structural, inertial, and solar dynamic operators. Basic instability characteristics of lag-pitch coupling through nonlinear terms are presented, and the effects of pitch control and torsional rigidity are clearly shown.
C.D.

**A87-15962#**
**ORBIT AND ATTITUDE CONTROL OF GEOSTATIONARY INERTIALLY ORIENTED LARGE FLEXIBLE PLATE-LIKE SPACECRAFT**
C. K. RAJASINGH (DFVLR, Cologne, West Germany) and S. K. SHRIVASTAVA (Indian Institute of Science, Bangalore, India) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p. refs
(IAF PAPER 86-245)

The design of a near optimal orbit and attitude control system for a flexible, rectangular, plate-like spacecraft in geostationary orbit with an inertial orientation is described. The spacecraft

requires a control system which balances the gravity gradient torque and controls the plate's orbit and attitude against disturbances. The proposed control system has four pairs of thrusters at the corners of the plate and ten sensors. The effect of structural flexibility on the control system is studied. An approach for eliminating the interaction, which involves adding a few flexural modes for control and changing the location of the thrusters, is proposed. I.F.

**A87-15963*#** Howard Univ., Washington, D. C.

**SYNTHESIS OF CONTROL LAWS FOR OPTIMALLY DESIGNED LARGE SPACE STRUCTURES**

K. SATYANARAYANA and P. M. BAINUM (Howard University, Washington, DC) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. Research supported by Howard University and NASA. refs

(IAF PAPER 86-246)

In this study, the vibration control of large space structures using the linear quadratic regulator technique is investigated. Emphasis is made on the control of both optimally designed structures and also the original (uniform) structures using the cantilever beam as an example. The open loop and closed loop eigenvalues are compared and the transient responses are obtained to determine the effectiveness of the control system design. Author

**A87-18319**

**CONTROL OF SOLAR BATTERY ARRAYS OF SPACECRAFT WITH CONSIDERATION OF THE STRUCTURAL FLEXIBILITY**

T. FUKUDA, H. HOSOGAI (Tokyo, Science University, Japan), N. YAJIMA (Ministry of International Trade and Industry, Mechanical Engineering Laboratory, Sakura, Japan), and Y. KURIBAYASHI IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 945-950. MOESC-supported research. refs

The problem dealt with here is how to estimate and control vibrational modes of flexible booms of solar arrays of spacecrafts in a reliable way, even in large angle attitude maneuvers. A proposed mode estimation method based on differential outputs of instrument solar cells and a linear optimal filtering is shown to give good estimation results of vibrational modes. It is shown here that even static output maximization control of the flexible solar array in a desired direction cannot work stably without flexibility consideration based on the mode estimation, and that the dynamic control can give good results to suppress the vibration of the arrays even in large angle attitude maneuvers. Furthermore, a reliable control method is shown to have fault tolerant properties, such as self-degradability as faults get worse. Author

**A87-18320**

**ATTITUDE CONTROL EXPERIMENT FOR FLEXIBLE SPACECRAFT**

K. YAMADA, T. KASHIWASE, M. INOUE, and K. TSUCHIYA (Mitsubishi Electric Corp., Central Research Laboratory, Amagasaki, Japan) IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1986, p. 951-956.

An attitude control problem for a flexible spacecraft with noncolocated sensor and actuator is considered. The plant dynamics has become a nonminimum phase system, and both the classical control theory and the modern control theory are applied to the controller design. Because the phase of the first vibration mode is opposite to that of the rigid body mode, the controller designed by the classical control theory becomes a nonminimum phase system as a necessary consequence. The designed controllers are verified by physical experiments as well as numerical simulations and these results show the good performance of the controllers. Author

**A87-18321**

**TRUNCATION ERROR ESTIMATION OF A SPACECRAFT MODEL WITH A FLEXIBLE APPENDAGE**

T. KAI and Y. OHKAMI (National Aerospace Laboratory, Chofu, Japan) IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 957-962. refs

A mathematical model expanded with constrained and unconstrained modes is presented for a control experimental model which is composed of a rigid part and an elastic part and is freely rotatable around one axis. Frequency response functions of the angle of rotation with respect to the control torque about the axis are derived. Zeros and poles of these functions are calculated and the differences between the two mode systems are shown for several inertial ratios of the rigid part to the elastic part. Author

**A87-18323**

**LOCAL OUTPUT-FEEDBACK CONTROL FOR LARGE FLEXIBLE SPACE STRUCTURES**

T. KIDA, I. YAMAGUCHI, and Y. OHKAMI (National Aerospace Laboratory, Chofu, Japan) IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 969-974. refs

This paper discusses the possibility of applying decentralized local control techniques to the LSS attitude/shape control problems. The proposed controller is implemented by feeding back only the local outputs and their feedback gains are designed based on the decomposed small-size subsystems. The preliminary results obtained are both on its stability properties and the estimation of its convergence speeds. A simple numerical example is introduced to illustrate the design procedures and the obtained results. Author

**A87-18490**

**LARGE-ANGLE SLEWING OF FLEXIBLE SPACECRAFT**

H. SOGA, K. HIRAKO (Toshiba Corp., Kawasaki, Japan), Y. OHKAMI, T. KIDA, and I. YAMAGUCHI (National Aerospace Laboratory, Chofu, Japan) IN: Space exploitation and utilization; Proceedings of the Symposium, Honolulu, HI, December 15-19, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 617-630.

(AAS PAPER 85-674)

A sub-optimal slewing control method is proposed for dealing with the slewing maneuver problem of a flexible spacecraft. The rigid body mode is controlled by an open-loop optimal controller of a design suitable for the optimal control approach such as the maximum principle. The elastic bending modes are regulated to nominal undeformed states by the optimal LQ regulator. The control law is obtained easily and can be realized in an on-board controller. The system is expected to be robust with regard to parameter errors and disturbances. Feasibility has been demonstrated through ground-based hardware experiments using a flexible spacecraft model mounted on a single-axis air-bearing table. D.H.

**A87-22396#**

**VIBRATION CONTROL OF NONLINEAR FLEXIBLE STRUCTURES**

IRA R. ASTRACHAN and RICHARD J. FOURNIER AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 7 p. NSF-supported research.

(AIAA PAPER 87-0074)

A simple yet effective method for controlling the undesired vibration of a nonlinear flexible structure is presented. The control system will detect anomalous motion, calculate the necessary restoring force, and implement that restoring force at the optimum time. The active vibration control system will keep the motion of the structure below a predetermined threshold during continuous excitation and significantly reduce the damping time required to recover from single random disturbances. The effectiveness of the control strategy is demonstrated through actual testing on a structural model. Author

**A87-22462*#** Cambridge Research Associates, Mass.
**FREQUENCY-SHAPED LARGE-ANGLE MANEUVERS**
HON M. CHUN, JAMES D. TURNER (Cambridge Research Associates, MA), and JES-NAN JUANG (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 17 p. refs
(AIAA PAPER 87-0174)

The paper considers the problem of maneuvering a flexible spacecraft through large angles in finite time. The basic control problem is divided into two parts. The first part consists of generating a frequency-shaped open-loop solution for the nonlinear rigid body as the nominal solution. The resulting two-point boundary-value problem is solved by introducing a continuation method for altering the mass distribution and boundary conditions for the spacecraft. For the second part, a feedback control is designed by linearizing the flexible body response about several points along the rigid body nominal solution. The perturbation gains are designed by using a frequency-shaped cost functional approach. The gains are linearly interpolated to produce smooth control time-histories as the linear piecewise constant plant models change during the maneuver. Author

**A87-22968#**
**FLEXIBILITY CONTROL OF SOLAR BATTERY ARRAYS. II - VIBRATION AND ATTITUDE CONTROL BASED ON STATE ESTIMATION OF DIFFERENTIAL SOLAR CELL SENSORS**
TOSHIO FUKUDA, HIDEMI HOSOKAI (Tokyo Science University, Japan), YUTAKA KURIBAYASHI (Mitsubishi Electric Corp., Kamakura, Japan), and NOBUYUKI YAJIMA (Ministry of International Trade and Industry, Mechanical Engineering Laboratory, Sakura, Japan) JSME, Bulletin (ISSN 0021-3764), vol. 29, Sept. 1986, p. 3116-3120. refs

In this paper, a differential solar cell sensor consisting of a pair of adjacent solar cells is proposed as a new type of sensors to measure vibration of flexible solar battery arrays and to orient the array toward the sun correctly. This sensor, which is small and light, has linear characteristics and can be implemented easily without compensation for distance. To eliminate noises in the sensor outputs, the Kalman filtering method is employed, based on the dynamics of a flexible solar array which is developed differently from the previous paper. Then all states can be fed back in an optimal closed control system, so that the control performance can be improved in vibration and attitude control. Author

**A87-22969#**
**FLEXIBILITY CONTROL OF SOLAR BATTERY ARRAYS. III VIBRATION AND ATTITUDE CONTROL WITH CONSIDERATION OF THE DYNAMICS OF A REACTION WHEEL AS AN ACTUATOR**
TOSHIO FUKUDA, HIDEMI HOSOKAI (Tokyo Science University, Japan), and NOBUYUKI YAJIMA (Ministry of International Trade and Industry, Mechanical Engineering Laboratory, Sakura, Japan) JSME, Bulletin (ISSN 0021-3764), vol. 29, Sept. 1986, p. 3121-3125.

**A87-23984#**
**NONLINEAR FEEDBACK CONTROL FOR REMOTE ORBITAL CAPTURE**
JOSEPH W. WIDHALM (USAF, Institute of Technology, Wright-Patterson AFB, OH) and BRUCE A. CONWAY (Illinois, University, Urbana) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 9, Nov.-Dec. 1986, p. 657-662. Previously cited in issue 20, p. 3000, Accession no. A86-43238. refs

**A87-23989*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**A SEQUENTIAL LINEAR OPTIMIZATION APPROACH FOR CONTROLLER DESIGN**
LUCAS G. HORTA, JER-NAN JUANG (NASA, Langley Research Center, Hampton, VA), and JOHN L. JUNKINS (Texas A & M University, College Station) (Guidance, Navigation and Control Conference, Snowmass, CO, Aug. 19-21, 1985, Technical Papers, p. 725-731) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 9, Nov.-Dec. 1986, p. 699-703. Previously cited in issue 22, p. 3239, Accession no. A85-45953. refs

**A87-23995#**
**EFFICIENT MODAL ANALYSIS OF DAMPED LARGE SPACE STRUCTURES**
TREVOR WILLIAMS (Kingston Polytechnic, Kingston-upon-Thames, England) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 9, Nov.-Dec. 1986, p. 722-724. SERC-supported research. refs

A novel eigenstructure perturbation technique that is valid for general feedback and minimizes numerical difficulties through the exclusive use of unitary transformations is presented. It is noted that these complex matrices (or their real subclass, the orthogonal matrices) are basic to nearly all numerically reliable algorithms developed in control theory. The method directly yields the order of error anticipated in its eigenvalue and eigenvector estimates. O.C.

**A87-24625**
**OPTIMAL SPACECRAFT ROTATIONAL MANEUVERS**
JOHN L. JUNKINS (Texas A & M University, College Station) and JAMES D. TURNER (PRA, Inc., Cambridge, MA) Research supported by the U.S. Air Force, Charles Stark Draper Laboratory, Inc., U.S. Navy, et al. Amsterdam and New York, Elsevier (Studies in Astronautics. Volume 3), 1986, 532 p. refs

Methods of solving problems related to maneuvering spacecraft are discussed, emphasizing the most central analytical and numerical methods for determining optimal rotational maneuvers of spacecraft. Large-angle nonlinear maneuvers are focused on, and large rotational maneuvers of flexible vehicles with simultaneous vibration suppression/arrest are considered. The individual chapters discuss: geometry and kinematics of rotational motion, basic principles of dynamics, rotational dynamics of rigid and multiple rigid body spacecraft, dynamics of flexible spacecraft, elements of optimal control theory, numerical solution of two point boundary value problems, optimal maneuvers of rigid spacecraft, optimal large-angle single-axis maneuvers of flexible spacecraft, frequency-shaped large-angle maneuvers of flexible spacecraft, and computational methods for closed-loop control problems. C.D.

**A87-24902#**
**DECENTRALIZED CONTROL OF MULTI-BODY SPACECRAFT - A NUMERICAL EXPERIMENT**
R. G. MELTON (Pennsylvania State University, University Park) and M. A. THAMES (General Electric Co., Astro Space Div., Valley Forge, PA) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 9 p. refs
(AIAA PAPER 87-0018)

This paper presents the results of numerical studies on the use of decentralized configuration control of spacecraft that can be modelled as tree topologies of rigid bodies with non-rigid connections. The decentralized scheme consists of each body having an autonomous controller that uses state information of that body and the adjacent body that is closer to the tree root. It is proposed that such a control structure would have several benefits of large modular spacecraft. The results indicate good performance, even for simple position and rate feedback loops in each body, leading to the suggestion that a rigorous stability analysis be undertaken to demonstrate the applicability of this control to a wider variety of spacecraft configurations. Author

**A87-27449**
**ON THE STABILITY OF MULTIPLE PARAMETER TIME-VARYING DYNAMIC SYSTEMS**
MEHDI AHMADIAN (Clemson University, SC) International Journal of Non-Linear Mechanics (ISSN 0020-7462), vol. 21, no. 6, 1986, p. 483-488. refs

A technique is presented for determining the stability of lumped-parameter, time-varying, dynamic systems with aperiodic coefficients. An 'energy like' function is used to develop stability conditions which are direct in terms of the coefficient matrices. The significance of what is presented here is twofold. First, it gives stability conditions applicable to systems which are not necessarily periodic. Second, it allows for a systematic categorization of the effects of the parameter changes on system response and stability, in order to provide a better understanding of the behavior of this class of dynamic systems as they arise in various areas of engineering. Author

**A87-30294*#** Virginia Polytechnic Inst. and State Univ., Blacksburg.
**AN ANALYTICAL AND EXPERIMENTAL STUDY OF A CONTROL SYSTEM'S SENSITIVITY TO STRUCTURAL MODIFICATIONS**
RAPHAEL T. HAFTKA, ZORAN N. MARTINOVIC, WILLIAM L. HALLAUER, JR., and GEORGE SCHAMEL (Virginia Polytechnic Institute and State University, Blacksburg) (Structures, Structural Dynamics, and Materials Conference, 26th, Orlando, FL, Apr. 15-17, 1985, Technical Papers. Part 2, p. 642-650) AIAA Journal (ISSN 0001-1452), vol. 25, Feb. 1987, p. 310-315. Previously cited in issue 13, p. 1855, Accession no. A85-30393. refs
(Contract NAG1-224)

**A87-31095*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**GROUND FACILITY FOR LARGE SPACE STRUCTURES DYNAMICS AND CONTROL VERIFICATION**
HENRY WAITES (NASA, Marshall Space Flight Center, Huntsville, AL) International Test and Evaluation Association, Symposium, Huntsville, AL, Sept. 30-Oct. 2, 1986, Paper. 20 p.

NASA Marshall Space Flight Center has developed a facility in which closed loop control of Large Space Structures (LSS) can be demonstrated and verified. The main objective of the facility is to verify LSS control system techniques so that on-orbit performance can be ensured. The facility consists of an LSS test article or payload which is connected to a 3-axis angular pointing mount assembly that provides control torque commands. The angular pointing mount assembly is attached to a base excitation system which will simulate disturbances most likely to occur for Orbiter and DOD payloads. The control computer contains the calibration software, the reference systems, the alignment procedures, the telemetry software, and the control algorithms. The total system is suspended in such a fashion that the LSS test article has the characteristics common to all LSS. Author

**N87-10166** Virginia Polytechnic Inst. and State Univ., Blacksburg.
**MANEUVER AND CONTROL OF FLEXIBLE SPACECRAFT Ph.D. Thesis**
R. D. QUINN 1985 171 p
Avail: Univ. Microfilms Order No. DA8605456

The problem of slewing large flexible structures in space and simultaneously suppressing vibrations is considered. The equations of motion for a three-dimensional spacecraft undergoing large rigid-body maneuvers are derived. The elastic motions are assumed to remain in the linear range. A method of substructures synthesis is presented which spatially discretizes the equations of motion. A perturbation approach is used to solve the equations of motion. The zero-order equations describing the rigid-body maneuver are independent of the first-order vibration problem which includes small rigid-body motions. The vibrational problem is described by linear nonself-adjoint equations with time dependent coefficients. Minimum-time, single-axis rotational maneuvers are considered. The axis of rotation is not necessarily a principal axis. The optimal maneuver force distribution is proportional to the corresponding rigid-body modes with the mass acting as the control gain. The premaneuver eigenvectors are used as admissible vectors to reduce the degree of freedom describing the vibration of the spacecraft during the maneuver. Natural control and uniform damping control are used to suppress the vibrations during the maneuver. Actuator dynamics cause a degradation of control performance. The inclusion of the actuator dynamics in the control formulation partially offsets this effect. The performance of these control techniques is adversely affected by actuator saturation but they remain effective. Numerical results are presented for a spacecraft in orbit and in an earth-based laboratory. Dissert. Abstr.

**N87-10891#** Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
**ON OPTIMAL PASSIVE AND ACTIVE CONTROL OF PRECISION SPACECRAFT STRUCTURES**
H. BAIER *In* ESA Proceedings of an International Conference on Spacecraft Structures p 35-39 Apr. 1986
Avail: NTIS HC A19/MF A01

The application of structural optimization and control methods for precision spacecraft structures is discussed. The necessity of proper decomposition into subproblems is emphasized. The shape adjustment and control of an antenna reflector is considered and results are presented. In the dynamic regime, active isolation is applied for a sensitive payload and the benefit of such an approach is outlined. For passive design purposes a control forces approach which is numerically efficient but does not necessarily lead to an optimum is used. ESA

**N87-10896#** Texas Univ., Austin.
**A STUDY OF NODAL COUPLING METHODS**
R. R. CRAIG *In* ESA Proceedings of an International Conference on Spacecraft Structures p 75-80 Apr. 1986
Avail: NTIS HC A19/MF A01

Component mode synthesis time-domain methods for undamped structures are introduced. Component normal modes with fixed or free boundaries, constraint modes, and inertia-relief attachment modes are described. An inertia attachment mode is defined. System eigensolutions based on various component mode sets are compared. Work on the application of attachment modes to modal control of flexible structures is noted. ESA

**N87-10945*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**PROCEEDINGS OF THE 2ND ANNUAL SCOLE WORKSHOP**
L. W. TAYLOR, JR., comp. Oct. 1986 268 p Workshop held in Hampton, Va., 9-10 Dec. 1985
(NASA-TM-89048; NAS 1.15:89048) Avail: NTIS HC A12/MF A01 CSCL 22B

Proceedings of the Second Annual Spacecraft Control Laboratory Experiment (SCOLE) Workshop held at the NASA Langley Research Center, Hampton, Va., December 9 to 10, 1985 are presented. Author

**N87-11766*#** Draper (Charles Stark) Lab., Inc., Cambridge, Mass.
**DUAL STRUCTURAL-CONTROL OPTIMIZATION OF LARGE SPACE STRUCTURES**
A. MESSAC and J. TURNER *In* NASA. Langley Research Center Recent Experiences in Multidisciplinary Analysis and Optimization, Part 2 28 p 1984
Avail: NTIS HC A22/MF A01 CSCL 22B

A new approach is proposed for solving dual structural-control optimization problems for high-order flexible space structures where reduced-order structural models are employed. For a given initial structural dessign, a quadratic control cost is minimized subject to a constant-mass constraint. The sensitivity of the optimal control cost with respect to the stuctural design variables is then determined and used to obtain successive structural redesigns using a contrained gradient optimization algorithm. This process is repeated until the constrained control cost sensitivity becomes negligible. A numerical example is presented which demonstrates

that this new approach effectively addresses the problem of dual optimization for potentially very high-order structures. Author

**N87-11829#** State Univ. of New York, Buffalo. Dept. of Mechanical and Aerospace Engineering.
**QUALITATIVE RESULTS FOR DISTRIBUTED SYSTEMS WITH DISCRETE AND STIFFNESS WITH APPLICATION TO CONTROL Final Report, 1 Jul. 1982 - 30 Jun. 1985**
D. J. INMAN 26 Aug. 1985 215 p
(Contract AF-AFOSR-0242-82)
(AD-A168622; AFOSR-86-0286TR) Avail: NTIS HC A10/MF A01 CSCL 22B

Distributed parameter models of large flexible space structures subject to various control techniques have been studied. The main thrust has been to develop qualitative results which are independent of truncation of discretization approaches by treating the fully distributed model. Emphasis has been on controlling the transient response of non-conservative linear partial differential equation models of such structures subject to a few point actuators. Inequalities have been developed between the stiffness and damping operators which when satisfied guarantee that the response of a self-adjoint system will be uniformly exponentially stable. In addition, it has been shown that the inequalities insure that finite dimensional versions of the control problem converge to an optimal control of the fully distributed system subject to compact feedback as the number of modes in the finite model increases. The inequality developed constitutes a generalization of the concept of underdamping normally used with single degree of freedom systems and provides a physical interpretation of the result. GRA

**N87-11834#** Teldix Luftfahrt-Ausruestungs G.m.b.H., Heidelberg (West Germany).
**LARGE WHEEL ACTUATORS DEFINITION STUDY Final Report**
H. HEIMEL and H. H. SCHULZ Paris ESA Dec. 1985 243 p
(Contract ESTEC-5907/84-NL-AN(SC))
(TELDIX-15-020-880; ESA-CR(P)-2265; ETN-86-98144) Avail: NTIS HC A11/MF A01

Large momentum wheels for attitude stabilization and maneuvering of large space vehicles and space structures were studied. Wheels with diameters of 50 and 80 cm and momentum ceilings of 300 and 1000 Nms, respectively, and control moment gyros (CMG) derived from them were considered. Spoked wheel designs are preferred, and data tables that define wheel families in each of the two size categories are provided. Suggestions for CMG devices bases on these wheels are presented. ESA

**N87-13788*#** Catholic Univ. of America, Washington, D.C. Dept. of Mechanical Engineering.
**STATIC DEFLECTION CONTROL OF FLEXIBLE BEAMS BY PIEZO-ELECTRIC ACTUATORS**
A. M. BAZ 19 Dec. 1986 43 p
(Contract NASA WORK ORDER 30429-D)
(NASA-CR-179947; NAS 1.26:179947) Avail: NTIS HC A03/MF A01 CSCL 20K

This study deals with the utilization of piezo-electric actuators in controlling the static deformation of flexible beams. An optimum design procedure is presented to enable the selection of the optimal location, thickness and excitation voltage of the piezo-electric actuators in a way that would minimize the deflection of the beam to which these actuators are bonded. Numerical examples are presented to illustrate the application of the developed optimization procedure in minimizing the structural deformation of beams of different materials when subjected to different loading and end conditions using ceramic or polymeric piezo-electric actuators. The results obtained emphasize the importance of the devised rational procedure in designing beam-actuator systems with minimal elastic distortions. Author

**N87-14402#** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
**FLUID DYNAMIC PROBLEMS IN SPACE SYSTEMS**
E. SLACHMUYLDERS, W. BERRY, D. N. SOO, and C. SAVAGE *In* ESA Proceedings of an International Symposium on Fluid Dynamics and Space p 65-82 Aug. 1986
Avail: NTIS HC A10/MF A01

Applications of fluid systems on spacecraft for propulsion, thermal control, and nutation damping are reviewed. Design problems posed by the high vacuum, microgravity environment of space and the dynamic interaction effects between the fluid systems and the spacecraft dynamic motion are discussed. Propellant management and tankage technology for operation in microgravity; liquid (propellants and cryogenic helium and hydrogen coolants) slosh interactions on spacecraft attitude control; control system rocket engine exhaust plume impingement effects; active thermal control systems using fluids; passive nutation damping using fluids; leak detection techniques for pressurized fluid systems operating in high vacuum; propellant contents gaging in microgravity; refuelling in orbit; and aerodynamic drag effects in low Earth orbits are considered. ESA

**N87-15263#** Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.
**OPTIMIZATION OF CLOSED LOOP EIGENVALUES: MANEUVERING, VIBRATION CONTROL AND STRUCTURE/CONTROL DESIGN ITERATION FOR FLEXIBLE SPACECRAFT Final Report, Jun. 1985 - May 1986**
JOHN L. JUNKINS 31 May 1986 151 p Prepared in cooperation with Texas A and M Univ., College Station
(Contract F49620-83-K-0032)
(AD-A172716; AFOSR-86-0905TR) Avail: NTIS HC A08/MF A01 CSCL 22B

This report summarizes new results on spacecraft dynamics and control. Perturbation methods are presented for computing nonlinear open and closed loop optimal maneuver control. Homotopy optimization algorithms are presented for tuning linear regulators vis-a-vis eigenvalue placement and robustness. A simultaneous structure/controller design optimization algorithm is developed. GRA

**N87-16017*#** Air Force Rocket Propulsion Lab., Edwards AFB, Calif. Interdisciplinary Space Technology Branch.
**SPACECRAFT DYNAMICS AND CONTROL PROGRAM AT AFRPL**
A. DAS, L. K. S. SLIMAK, and W. T. SCHLOEGEL *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 25-40 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 22B

A number of future DOD and NASA spacecraft such as the space based radar will be not only an order of magnitude larger in dimension than the current spacecraft, but will exhibit extreme structural flexibility with very low structural vibration frequencies. Another class of spacecraft (such as the space defense platforms) will combine large physical size with extremely precise pointing requirement. Such problems require a total departure from the traditional methods of modeling and control system design of spacecraft where structural flexibility is treated as a secondary effect. With these problems in mind, the Air Force Rocket Propulsion Laboratory (AFRPL) initiated research to develop dynamics and control technology so as to enable the future large space structures (LSS). AFRPL's effort in this area can be subdivided into the following three overlapping areas: (1) ground experiments, (2) spacecraft modeling and control, and (3) sensors and actuators. Both the in-house and contractual efforts of the AFRPL in LSS are summarized. Author

**N87-16018*#** Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
**FLIGHT DYNAMICS LABORATORY OVERVIEW**
THADDEUS SANDFORD *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 41-65 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 22B

The Flight Dynamics Laboratory (FDL) is one of four Air Force Wright Aeronautical Laboratories (AFWAL) and part of the Aeronautical Systems Division located at Wright-Patterson AFB, Ohio. The FDL is responsible for the planning and execution of research and development programs in the areas of structures and dynamics, flight controls, vehicle equipment/subsystems, and aeromechanics. Some of the areas being researched in the four FDL divisions are as follows: large space structures (LSS) materials and controls; advanced cockpit designs; bird-strike-tolerant windshields; and hypersonic interceptor system studies. Two of the FDL divisions are actively involved in programs that deal directly with LSS control/structures interaction: the Flight Controls Division and the Structures and Dynamics Division. Author

**N87-16020*#** Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
**PACOSS PROGRAM OVERVIEW AND STATUS**
L. C. ROGERS and K. E. RICHARDS, JR. (Martin Marietta Aerospace, Denver, Colo.) *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 85-109 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 22B

Many future civilian and military large space structures (LSS) will have as performance objectives stringent pointing accuracies, short settling times, relatively fast response requirements, or combinations thereof. Many of these structures will be large, light weight, and will exhibit high structural modal density at low frequency and within the control bandwidth. Although it is possible in principle to achieve structural vibration control through purely active means, experience with complex structures has shown that the realities of plant model inaccuracies and sensor/actuator dynamics frequently combine to produce substandard performance. A more desirable approach is to apply passive damping technology to reduce the active control burden. Development of the technology to apply this strategy is the objective of the PACOSS (Passive and Active Control OF Space Structures) program. A key element in the PACOSS program is the Representative System Article (RSA). The RSA is a generic paper system that serves as a testbed for damping and controls studies. It also serves as a basis for design of the smaller Dynamic Test Article (DTA), a hardware testbed for the laboratory validation of analysis and design practices developed under PACOSS. Author

**N87-16028*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**COFS 1: BEAM DYNAMICS AND CONTROL TECHNOLOGY OVERVIEW**
JOHN L. ALLEN *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 221-232 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 20N

The Control of Flexible Structures (COFS) 1 Project provides the invaluable opportunity to test, validate, and measure the effectiveness of theories, structural concepts, control systems, and flight certification processes for future missions through a research program focusing on multiple issues in large flexible structures, dynamics, and controls. The COFS 1 Project consists of a series of ground and flight activities building progressively from modeling and dynamic characterization of large space systems to the more complex issues of flexible-body control. The program objectives are to: determine the degree to which theory and ground testing can predict flight performance of next-generation low-frequency structures; evaluate structural fidelity of representative next-generation large deployable precision structure; assess math modeling requirements for large lightweight complex systems on which ground test results are questionable; determine degree to which scale model analysis and tests can be correlated to full-scale performance; evaluate system identification and state estimation algorithms on complex lightweight structures in the space environment; evaluate and verify controls/structures modeling capability; evaluate control laws and control systems; and evaluate damping effects in micro-g environment. Author

**N87-16029*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**COFS 1 RESEARCH OVERVIEW**
G. C. HORNER *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 233-251 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 22A

The Control of Flexible Structures (COFS) program is divided into three areas of research. These three areas are controls/structures analysis development, ground test experiments, and in-space experiments. The ground test experiments are intended to validate analyses and to confirm through hardware tests our technical readiness to successfully fly the Mast hardware. There is this close relation to the results of ground tests and analytical predictions that must be understood before flight experiments may be attempted. Details relative to each program area are given. Author

**N87-16032*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**MAST FLIGHT SYSTEM DYNAMIC PERFORMANCE**
L. DAVIS, D. HYLAND, T. OTTEN, and F. HAM *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 281-298 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 20K

The MAST Flight System as a test bed for large space structure control algorithms is discussed. An overview is given of the control system architecture. The actuators, the sensors, the control computer, and the baseline damping algorithm are discussed. R.J.F.

**N87-16034*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**COFS 1 GUEST INVESTIGATOR PROGRAM**
ANTHONY FONTANA and ROBERT L. WRIGHT *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 319-325 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 22A

The process for selecting guest investigators for participation in the Control of Flexible Structures (COFS)-1 program is described. Contracts and grants will be awarded in late CY87. A straw-man list of types of experiments and a distribution of the experiments has been defined to initiate definition of an experiments package which supports development and validation of control structures interaction technology. A schedule of guest investigator participation has been developed. Author

**N87-16035*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**COFS 2: 3-D DYNAMICS AND CONTROLS TECHNOLOGY**
JON S. PYLE *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 327-345 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 22B

The Control of Flexible Structures (COFS) 2 project is a complex and ambitious undertaking which will address several critical technology areas. Among them are modeling, structural dynamics, controls, and ground testing issues which are not only germane to this effort, but to other large space structure programs being contemplated. This effort requires the early integration of controls and structural dynamics considerations in order to achieve mission success. Several technology advances must be achieved in the areas of system modelling, control synthesis and methodology, sensor/actuator development, and ground testing techniques for system evaluation and on-orbit performance prediction and verification. This project offers a unique opportunity for the integration of several disciplines to produce technology advances which will benefit many future programs. In addition, the opportunities available to participate in the various levels in the

phase of this project, e.g., analytical development and modelling, ground testing, and flight testing, permit for the involvement of a significant number of interested researchers and organizations from government, universities and industry. Author

**N87-16037*#** General Electric Co., Philadelphia, Pa. Space Div.

**CONCEPTUAL DESIGN OF POINTING CONTROL SYSTEMS FOR SPACE STATION GIMBALLED PAYLOADS**

ROBERT O. HUGHES *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 371-381 Nov. 1986 Previously announced as A86-47411

Avail: NTIS HC A23/MF A01 CSCL 22B

A conceptual design of the control system for Payload Pointing Systems (PPS) is developed using classic Proportional-Integral-Derivatives (PID) techniques. The major source of system pointing error is due to the disturbance-rich environment of the space station in the form of gimbal baseplate motions. These baseplate vibrations are characterized using Fast Fourier Transform (FFT) techniques. Both time domain and frequency domain dynamic models are developed to assess control system performance. Three basic methods exist for the improvement of PPS pointing performance: increase control system bandwidth, add Image Motion Compensation, and/or reduce (or change) the baseplate disturbance environment. Author

**N87-16038*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**DESIGN CONSIDERATIONS FOR JOINTS IN DEPLOYABLE SPACE TRUSS STRUCTURES**

MARVIN D. RHODES *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 383-398 Nov. 1986

Avail: NTIS HC A23/MF A01 CSCL 20K

All of the structures considered for the Control of Flexible Structures (COFS) flight experiments are deployable truss structures and their response will be dominated by the structural response of the joints. To prepare for these experiments some fundamental research work is being conducted in the Structures and Dynamics Division at LaRC which will provide insight into structurally efficient and predictable deployable truss joints. This work involves generic studies of the static and dynamic response of joints as well as the development of analytical models which can be used to predict the response of a large multijointed truss. In addition to the generic joint studies, the research effort encompasses the design and fabrication of a 20-meter long deployable truss beam for laboratory evaluation of its structural characteristics and correlation with developed prediction methods. The experimental results have indicated the importance of attention to detail in the design and fabrication of joints for deployable truss structures. The dimensional relations and material considerations for efficient pin-clevis joints have been outlined. Results of tests on the near-center latch are discussed. Author

**N87-16044*#** Lockheed Missiles and Space Co., Sunnyvale, Calif.

**PASSIVE DAMPING AUGMENTATION FOR FLEXIBLE STRUCTURES**

J. R. SESAK, M. J. GRONET, and G. M. MARINOS *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 475-493 Nov. 1986

Avail: NTIS HC A23/MF A01 CSCL 22B

The present work concentrates on the application and extension of absorber design and optimization techniques to a multimode, multi-DOF, large space structure, namely the NASA space station. The principal issue addressed is the optimal tuning of several absorbers for the transient response of a multi-DOF system, including the effects of modal coupling, existing structural damping, absorber placement, and adsorber mass. The space station is subject to many transient disturbances such as docking, orbit reboost, crew motion, and payload slewing. A notable steady-state excitation source is the Science Research Centrifuge, which rotates at a frequency in the bandwidth of the primary structural modes. Because of the relatively advanced state of development of steady-state absorber design techniques, only the transient cases are considered in this study. Author

**N87-16046*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**ANALYSIS AND SIMULATION OF THE MAST (COFS-1 FLIGHT HARDWARE)**

LUCAS G. HORTA, JOANNE L. WALSH, GARNETT C. HORNER, and JAMES P. BAILEY (PRC Kentron, Inc., Hampton, Va.) *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 515-532 Nov. 1986

Avail: NTIS HC A23/MF A01 CSCL 22B

In-house analysis work in support of the Control of Flexible Structures (COFS) program is being performed at the NASA Langley Research Center. The work involves evaluation of the proposed design configuration, controller design as well as actuator dynamic modeling, and MAST/actuator dynamic simulation of excitation and damping. A complete finite element model of the MAST has been developed. This finite element model has been incorporated into an optimization procedure which minimizes total mass while maintaining modal coupling. Results show an increase in the total mass due to additional constraints (namely, the diagonal frequency constraint) imposed on the baseline design. A valid actuator dynamic model is presented and a complete test sequence of the proposed flight experiment is demonstrated. The actuator dynamic model is successfully used for damping and the stroke limitations for first mode excitation are demonstrated. Plans are to incorporate additional design variables and constraints into the optimization procedure (such as actuator location) and explore alternative formulations of the objective function. A different actuator dynamic model to include hardware limitations will be investigated. Author

**N87-16048*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**ROBUST MULTIVARIABLE CONTROLLER DESIGN FOR FLEXIBLE SPACECRAFT**

SURESH M. JOSHI and ERNEST S. ARMSTRONG *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 547-562 Nov. 1986

Avail: NTIS HC A23/MF A01 CSCL 22B

Large, flexible spacecraft are typically characterized by a large number of significant elastic modes with very small inherent damping, low, closely spaced natural frequencies, and the lack of accurate knowledge of the structural parameters. Summarized here is some recent research on the design of robust controllers for such spacecraft, which will maintain stability, and possible performance, despite these problems. Two types of controllers are considered, the first being the linear-quadratic-Guassian-(LQG)-type. The second type utilizes output feedback using collocated sensors and actuators. The problem of designing robust LQG-type controllers using the frequency domain loop transfer recovery (LTR) method is considered, and the method is applied to a large antenna model. Analytical results regarding the regions of stability for LQG-type controllers in the presence of actuator nonlinearities are also presented. The results obtained for the large antenna indicate that the LQG/LTR method is a promising approach for control system design for flexible spacecraft. For the second type of controllers (collocated controllers), it is proved that the stability is maintained in the presence of certain commonly encountered nonlinearities and first-order actuator dynamics. These results indicate that collocated controllers are good candidates for robust control in situations where model errors are large. Author

**N87-16341*#** Lockheed Missiles and Space Co., Sunnyvale, Calif.
**DISCRETE MECHANISM DAMPING EFFECTS IN THE SOLAR ARRAY FLIGHT EXPERIMENT**
E. D. PINSON *In* NASA. Lewis Research Center The 20th Aerospace Mechanics Symposium p 277-289 May 1986
Avail: NTIS HC A14/MF A01 CSCL 20K

Accelerometer data were collected during on-orbit structural dynamic testing of the Solar Array Flight Experiment aboard the Space Shuttle, and were analyzed at Lockheed Missile and Space Co. to determine the amount of damping present in the structure. The results of this analysis indicated that the damping present in the fundamental in-plane mode of the structure substantially exceeded that of the fundamental out-of-plane mode. In an effort to determine the source of the higher in-plane damping, a test was performed involving a small device known as a constant-force spring motor or constant-torque mechanism. Results from this test indicate that this discrete device is at least partially responsible for the increased in-plane modal damping of the Solar Array Flight Experiment structure. Author

**N87-16366#** Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
**DAMPING 1986 PROCEDURES, VOLUME 2 Summary Report, Feb. 1984 - Feb. 1986**
E. D. PINSON, D. W. NICHOLSON, M. G. PRASAD, R. H. LIN, and B. K. WADA May 1986 614 p
(AD-A173950; AFWAL-TR-86-3059-VOL-2) Avail: NTIS HC A99/MF A01 CSCL 20K

Individual conference papers are presented. Some of the titles include: Damping Characteristics of the Solar Array Flight Experiment; Resonant Shift Modal Testing Method for Viscous Damping Coefficient Estimation; Prediction of Spacecraft Damping; On Orbit Flexible Body Parameter Identification for Space Station; Design and Analysis of the PACOSS Representative System; Robust Control Design for Vibration Suppression of Large Space Structures; Active Augmentation of a Passively Damped Representative Large Space System; Active Control for Vibration Damping; A New Approach to Modeling Linear Viscoelastic Damping for Space Structures; Experimental Investigations Into Passive and Active Control Using Space Realized Techniques; Material Damping in Aluminum and Metal Matrix Materials; Material Damping in Space Structures; Specific Damping Capacity of Metal Matrix Composites in Tension Tension Fatigue; Response Suppression in Composite Sandwich Shells; Prediction of Material Damping of Laminated Polymer Matrix Composites; The Influence of Fiber Length and Fiber Orientation on Damping and Stiffness of Polymer Composite Materials; A Review of the Damping Mechanisms in Advanced Fiber Reinforced Plates; Damping Measurements by Hilbert Transform on Composite Materials; and A Comparison Among Damping Coefficients on Several Aerospace Composite Materials. GRA

**N87-16766*#** Alabama Univ., Huntsville. Dept. of Mathematics.
**STOCHASTIC MODELING AND CONTROL SYSTEM DESIGNS OF THE NASA/MSFC GROUND FACILITY FOR LARGE SPACE STRUCTURES: THE MAXIMUM ENTROPY/OPTIMAL PROJECTION APPROACH**
WEI-SHEN HSIA *In* NASA. Marshall Space Flight Center Research Reports: 1986 NASA/ASEE Summer Faculty Fellowship Program 13 p Nov. 1986
Avail: NTIS HC A99/MF E04 CSCL 22B

In the Control Systems Division of the Systems Dynamics Laboratory of the NASA/MSFC, a Ground Facility (GF), in which the dynamics and control system concepts being considered for Large Space Structures (LSS) applications can be verified, was designed and built. One of the important aspects of the GF is to design an analytical model which will be as close to experimental data as possible so that a feasible control law can be generated. Using Hyland's Maximum Entropy/Optimal Projection Approach, a procedure was developed in which the maximum entropy principle is used for stochastic modeling and the optimal projection technique is used for a reduced-order dynamic compensator design for a high-order plant. Author

**N87-16848*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**DESCRIPTION OF THE SPACECRAFT CONTROL LABORATORY EXPERIMENT (SCOLE) FACILITY**
JEFFREY P. WILLIAMS and ROSEMARY A. RALLO (Purdue Univ., West Lafayette, Ind.) Jan. 1987 45 p
(NASA-TM-89057; NAS 1.15:89057) Avail: NTIS HC A03/MF A01 CSCL 01C

A laboratory facility for the study of control laws for large flexible spacecraft is described. The facility fulfills the requirements of the Spacecraft Control Laboratory Experiment (SCOLE) design challenge for laboratory experiments, which will allow slew maneuvers and pointing operations. The structural apparatus is described in detail sufficient for modelling purposes. The sensor and actuator types and characteristics are described so that identification and control algorithms may be designed. The control implementation computer and real-time subroutines are also described. Author

**N87-16861*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**STRUCTURAL DYNAMICS AND ATTITUDE CONTROL STUDY OF EARLY MANNED CAPABILITY SPACE STATION CONFIGURATIONS**
J. KIRK AYERS (PRC Kentron, Inc., Hampton, Va.), WILLIAM M. CIRILLO, DANIEL P. GIESY, JAY C. HITCHCOCK, MARTIN J. KASZUBOWSKI, and J. PHILIP RANEY Jan. 1987 69 p
(NASA-TM-89078; NAS 1.15:89078) Avail: NTIS HC A04/MF A01 CSCL 22B

A study was performed to determine the vibration and attitude control characteristics of critical space station configurations featuring early manned capability during buildup from initial user support through the operations capability reference station. Five configurations were selected and were examined thus determining the changes that are likely to occur in the characteristics of the system as the station progresses from a single boom structure to a mature, dual keel, operations capability reference station. Both 9 foot and 5 meter truss bay sizes were investigated. All configurations analyzed were stable; however, the 5 meter truss bay size structure exhibited superior stability characteristics. Author

**N87-16864*#** PRC Kentron, Inc., Hampton, Va.
**SPACECRAFT ATTITUDE CONTROL MOMENTUM REQUIREMENTS ANALYSIS**
BRENT P. ROBERTSON and MICHAEL L. HECK (Analytical Mechanics Associates, Inc., Hampton, Va.) Jan. 1987 92 p
(Contract NAS1-18000; NAS1-17958)
(NASA-CR-178219; NAS 1.26:178219) Avail: NTIS HC A05/MF A01 CSCL 22B

The relationship between attitude and angular momentum control requirements is derived for a fixed attitude, Earth orbiting spacecraft with large area articulating appendages. Environmental effects such as gravity gradient, solar radiation pressure, and aerodynamic forces arising from a dynamic, rotating atmosphere are examined. It is shown that, in general, each environmental effect contributes to both cyclic and secular momentum requirements both within and perpendicular to the orbit plane. The gyroscopic contribution to the angular momentum control requirements resulting from a rotating, Earth oriented spacecraft is also discussed. Special conditions are described where one or more components of the angular momentum can be made to vanish, or become purely cyclical. Computer generated plots for a candidate space station configuration are presented to supplement the analytically derived results. Author

**N87-16872#** Oklahoma Univ., Norman. Dept. of Mathematics.
**ESTIMATION AND CONTROL OF DISTRIBUTED MODELS FOR CERTAIN ELASTIC SYSTEMS ARISING IN LARGE SPACE STRUCTURES Annual Report, 2 Jul. 1984 - 1 Jan. 1986**
LUTHER W. WHITE 1986 7 p
(Contract AF-AFOSR-0271-84)
(AD-A175019; AFOSR-86-2193TR) Avail: NTIS HC A02/MF A01 CSCL 20K

This project is to study the estimation and control of elastic systems composed of beams and plates in order to develop efficient and accurate estimation and control algorithms. Results have been obtained for the estimation in static beams and plates, control and location of actuators for static beams and plates, and identifiability for discrete approximations of second order elliptic boundary value problems. Currently testing codes are being developed for numerical experimentation for estimation of damping and elastic coefficients in dynamic linear plate models, estimation of boundary parameters for second order elliptic problems, estimation of elastic coefficients in cantilevered beams using perturbed boundary conditions, optimal location of actuators for the control of beams, and control of plates through forces at points and forces distributed over sets of small measure and curves. The plan is to next investigate boundary control and estimation, estimation and control in structures, use of friction as an active control, and parallelization of estimation and control algorithms.
GRA

**N87-16947#** Ricerche e Progetti s.r.l., Turin (Italy).
**DYNAMICS AND CONTROL ANALYSIS PACKAGE (DCAP): AN AUTOMATED ANALYSIS AND DESIGN TOOL FOR STRUCTURAL CONTROL OF SPACE STRUCTURES**
R. P. SINGH, R. J. VANDERVOORT, C. ARDUINI, A. FESTA (Aeritalia S.p.A., Torino, Italy), C. MACCONE, and D. SCIACOVELLI (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 211-218 Aug. 1986
Avail: NTIS HC A12/MF A01

The Dynamics and Control Analysis Package (DCAP) automated design and checking tool for the dynamics and control of large flexible structures is described. The DCAP includes programs for nonlinear simulation of multibody systems dynamics; linear or linearized system analysis with frequency and time domain response, stability and sensitivity analysis; modal analysis and order reduction; and control design. It is presently being endowed with a user friendly interactive preprocessor, higher speed capabilities, and an LQG package providing for both analog and digital controls.
ESA

**N87-17449** Stanford Univ., Calif.
**ADAPTIVE CONTROL OF A FLEXIBLE STRUCTURE Ph.D. Thesis**
MICHAEL DAVID SIDMAN 1986 205 p
Avail: Univ. Microfilms Order No. DA8619822

The demonstration of a high-performance adaptive control system for a lightly-damped flexible mechanical structure, such as found in large space structures, lightweight robots, and computer peripherals, is discussed. The system accurately identifies the frequencies of three resonances and one anti-resonance, as well as the overall gain of the experimental plant, the Stanford Four Disk System. The robustness and reliability of the system were demonstrated in the presence of large, sudden changes in plant dynamics that include a complex pole-zero flip and near pole-zero cancellation that occur as payload mass is added to the system. Fixed-gain robust control performance, both colocated and noncolocated, are compared to noncolocated adaptive control performance. A new method of pole-placement ensures excellent reference-command step responses, substantial active damping of modeled modes, modest amount of control effort and low computational intensity despite major changes in plant dynamics. Techniques ensure stable control, at least a minimum level of performance at all times and fast recovery after large sudden changes in plant parameters that occur even while the plant is in a quiescent state.
Dissert. Abstr.

**N87-17821*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**PROCEEDINGS OF THE 3RD ANNUAL SCOLE WORKSHOP**
LAWRENCE W. TAYLOR, JR., comp. Jan. 1987 457 p
Workshop held in Hampton, Va., 17-18 Nov. 1986; sponsored by NASA Langley Research Center and California Univ., Los Angeles
(NASA-TM-89075; NAS 1.15:89075) Avail: NTIS HC A20/MF A01 CSCL 22B

Topics addressed include: modeling and controlling the Spacecraft Control Laboratory Experiment (SCOLE) configurations; slewing maneuvers; mathematical models; vibration damping; gravitational effects; structural dynamics; finite element method; distributed parameter system; on-line pulse control; stability augmentation; and stochastic processes.

**N87-17822*#** Howard Univ., Washington, D. C.
**ISSUES IN MODELING AND CONTROLLING THE SCOLE CONFIGURATION**
PETER M. BAINUM, A. S. S. R. REDDY, CHEICK MODIBO DIARRA, and FEIYUE LI *In* NASA. Langley Research Center Proceedings of the 3rd Annual SCOLE Workshop p 11-67 Jan. 1987
Avail: NTIS HC A20/MF A01 CSCL 22B

The parametric study of the in-plane Spacecraft Control Laboratory Experiment (SCOLE) system, the Floquet Stability Analysis, and three dimensional formulations of the SCOLE system dynamics are examined. Control issues are discussed, such as: control of large structures with delayed input in continuous time; control with delayed input in discrete time; control law design for SCOLE using Linear Quadratic Gaussian (LQC)/TRR technique; and optimal torque control for SCOLE slewing maneuvers. B.G.

**N87-17823*#** Howard Univ., Washington, D. C. Dept. of Mechanical Engineering.
**OPTIMAL TORQUE CONTROL FOR SCOLE SLEWING MANEUVERS**
P. M. BAINUM and FEIYUE LI *In* NASA. Langley Research Center Proceedings of the 3rd Annual SCOLE Workshop p 69-82 Jan. 1987
Avail: NTIS HC A20/MF A01 CSCL 22B

The Spacecraft Control Laboratory Experiment (SCOLE) was slewed from one attitude to the required attitude and an integral performance index which involves the control torques was minimized. Kinematic and dynamical equations, optimal control, two-point boundary-value problems, and estimation of unknown boundary conditions are presented. B.G.

**N87-17825*#** North Carolina Univ., Charlotte. Dept. of Electrical Engineering.
**SLEW MANEUVER DYNAMICS OF THE SPACECRAFT CONTROL LABORATORY EXPERIMENT**
Y. P. KAKAD *In* NASA. Langley Research Center Proceedings of the 3rd Annual SCOLE Workshop p 93-108 Jan. 1987
Avail: NTIS HC A20/MF A01 CSCL 22B

Mathematical expressions for slew maneuver dynamics are presented. The total kinetic energy expression of the system is given as $T = T(0) + T(1) + T(2)$, where T(0), T(1), and T(2) refer to the kinetic energies of the shuttle, the flexible beam, and the tip mass (the reflector), respectively. The specific equations for each of these are defined and integrated into the total energy expression. Using the chain rule in the Lagrange equations and an expression allowing the transformation of the orbiter angular velocity from the inertial frame to the body-fixed frame, the rotational equations are obtained. Finally, the vibration equations for the beam are derived, again using the Lagrange equations.
M.G.

**N87-17827*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**ON INCORPORATING DAMPING AND GRAVITY EFFECTS IN MODELS OF STRUCTURAL DYNAMICS OF THE SCOLE CONFIGURATION**

LARRY TAYLOR, TERRY LEARY (George Washington Univ., Washington, D.C.), and ERIC STEWART *In its* Proceedings of the 3rd Annual SCOLE Workshop p 121-148 Jan. 1987

Avail: NTIS HC A20/MF A01 CSCL 22B

The damping for structural dynamic models of flexible spacecraft is usually ignored and then added after modal frequencies and mode shapes are calculated. It is common practice to assume the same damping ratio for all modes, although it is known that damping due to bending and that due to torsion are sometimes ignored. Two methods of including damping in the modeling process from its onset are examined. First, the partial derivative equations of motion are analyzed for a pinned-pinned beam with damping. The end conditions are altered to handle bodies with mass and inertia for the Spacecraft Control Laboratory Experiment (SCOLE) configuration. Second, a massless beam approximation is used for the modes with low frequencies, and a clamped-clamped system is used to approximate the modes for arbitrarily high frequency. The model is then modified to include gravity effects and is compared with experimental results. Author

**N87-17834*#** University of Southern California, Los Angeles.

**EVALUATION OF ON-LINE PULSE CONTROL FOR VIBRATION SUPPRESSION IN FLEXIBLE SPACECRAFT**

G. A. BEKEY, S. F. MASRI, and R. K. MILLER *In* NASA. Langley Research Center Proceedings of the 3rd Annual SCOLE Workshop p 337-366 Jan. 1987

Avail: NTIS HC A20/MF A01 CSCL 22B

On-line pulse control for vibration suppression in a flexible spacecraft was evaluated. A continuous beam vs. a truss was modeled. A linear finite element model was used to determine the truss characteristics. Control issues outlined are ED pulse actuator development, pseudo pulse algorithm development, and large nonlinear simulation problems. E.R.

**N87-17835*#** California Univ., Los Angeles. Dept. of Electrical Engineering.

**ACTIVE STABILITY AUGMENTATION OF LARGE SPACE STRUCTURES: A STOCHASTIC CONTROL PROBLEM**

A. V. BALAKRISHNAN *In* NASA. Langley Research Center Proceedings of the 3rd Annual SCOLE Workshop p 367-384 Jan. 1987 Presented at the IFAC Conference on Stochastic Control, Vilnius, May 1986

(Contract NAG1-464)

Avail: NTIS HC A20/MF A01 CSCL 22B

A problem in SCOLE is that of slewing an offset antenna on a long flexible beam-like truss attached to the space shuttle, with rather stringent pointing accuracy requirements. The relevant methodology aspects in robust feedback-control design for stability augmentation of the beam using on-board sensors is examined. It is framed as a stochastic control problem, boundary control of a distributed parameter system described by partial differential equations. While the framework is mathematical, the emphasis is still on an engineering solution. An abstract mathematical formulation is developed as a nonlinear wave equation in a Hilbert space. That the system is controllable is shown and a feedback control law that is robust in the sense that it does not require quantitative knowledge of system parameters is developed. The stochastic control problem that arises in instrumenting this law using appropriate sensors is treated. Using an engineering first approximation which is valid for small damping, formulas for optimal choice of the control gain are developed. Author

**N87-17836*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**THE SCOLE DESIGN CHALLENGE**

LARRY TAYLOR and A. V. BALAKRISHNAN (California Univ., Los Angeles) *In* NASA. Langley Research Center Proceedings of the 3rd Annual SCOLE Workshop p 385-412 Jan. 1987

Avail: NTIS HC A20/MF A01 CSCL 22B

An NASA program is discussed which was initiated to make direct comparisons of control laws for, first, a mathematical problem, than an experimental test article is being assembled under the cognizance of the Spacecraft Control Branch. The physical apparatus will consist of a softly supported dynamic model of an antenna attached to the Shuttle by a flexible beam. The control objective will include the task of directing the line of sight of the Shuttle/antenna configuration toward a fixed target, under conditions of noisy data, limited control authority and random disturbances. A workshop will be planned to discuss and compare results of the design challange. Author

**N87-17837*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**DESCRIPTION OF THE SPACECRAFT CONTROL LABORATORY EXPERIMENT (SCOLE) FACILITY**

JEFFREY P. WILLIAMS and ROSEMARY A. RALLO *In its* Proceedings of the 3rd Annual SCOLE Workshop p 413-458 Jan. 1987

Avail: NTIS HC A20/MF A01 CSCL 22B

A laboratory facility for the study of control laws for large flexible spacecraft is described. The facility fulfills the requirements of the Spacecraft Control Laboratory Experiment (SCOLE) design challenge for a laboratory experiment, which will allow slew maneuvers and pointing operations. The structural apparatus is described in detail sufficient for modelling purposes. The sensor and actuator types and characteristics are described so that identification and control algorithms may be designed. The control implementation computer and real-time subroutines are also described. Author

**N87-17845#** Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Aerospace and Ocean Engineering.

**EXPERIMENTAL STUDY OF ACTIVE VIBRATION CONTROL Annual Technical Report, 1 Jan. 1985 - 30 Jan. 1986**

WILLIAM L. HALLAUER, JR. and ANTHONY J. KUBIS, JR. 31 Jul. 1986 88 p

(Contract F49620-85-C-0024)

(AD-A173144; AFOSR-86-1003TR) Avail: NTIS HC A05/MF A01 CSCL 22B

Complementary experimental-theoretical studies were conducted on three separate topics, all of which are related to the dynamics and control of highly flexible large space structures (LSS) in Earth orbit: (1) active damping of vibrations; (2) structural wave propagation; and (3) development of small, flexible laboratory structures having a maneuverable rigid body mode. In the active damping study on a laboratory structure of moderate modal complexity, very good agreement was achieved between experimental measurements and theoretical predictions. The type of active damping applied, output feedback with dual (colocated) control sensors and actuators, should be considered as a candidate for implementation on first-generation LSS because of its stability robustness. The study of wave propagation is focused primarily on transient flexural response of a two-dimensional grid structure to a suddenly applied sinusoidal force at one point. The study is not completed, so results are not presented. New laboratory structures with a maneuverable rigid body mode were built and analyzed. They were relatively simple planar structures composed of thin-walled beam members. They exhibited some unusual dynamic characteristics such as variable natural frequencies, snap buckling, and other nonlinearities. Finite element modeling generally failed to predict the measured vibration modes and the unusual characteristics. GRA

**N87-18880*#** Catholic Univ. of America, Washington, D.C. Dept. of Mechanical Engineering.
**OPTIMUM VIBRATION CONTROL OF FLEXIBLE BEAMS BY PIEZO-ELECTRIC ACTUATORS**
A. BAZ and S. POH Mar. 1987 71 p
(Contract NAG5-250; NASA ORDER 30429-D)
(NASA-CR-180209; NAS 1.26:180209) Avail: NTIS HC A04/MF A01 CSCL 20K

The utilization of piezoelectric actuators in controlling the structural vibrations of flexible beams is examined. A Modified Independent Modal Space Control (MIMSC) method is devised to enable the selection of the optimal location, control gains and excitation voltage of the piezoelectric actuators in a way that would minimize the amplitudes of vibrations of beams to which these actuators are bonded, as well as the input control energy necessary to suppress these vibrations. The developed method accounts for the effects that the piezoelectric actuators have on changing the elastic and inertial properties of the flexible beams. Numerical examples are presented to illustrate the application of the developed MIMSC method in minimizing the structural vibrations of beams of different materials when subjected to different loading and end conditions using ceramic or polymeric piezoelectric actuators. The obtained results emphasize the importance of the devised method in designing more realistic active control systems for flexible beams, in particular, and large flexible structures in general. Author

**N87-19434#** Boston Univ., Mass.
**THE CONTROL THEORY OF FLEXIBLE AND ARTICULATED SPACECRAFT Interim Report, 15 Apr. 1985 - 14 Apr. 1986**
JOHN BAILLIEUL and MARK LEVI 15 May 1986 45 p
(Contract AF-AFOSR-0144-85)
(AD-A174880; AFOSR-86-2082TR) Avail: NTIS HC A03/MF A01 CSCL 22B

This report summarizes work done on the dynamics and control of flexible and articulated spacecraft. The combined dynamical effects of elasticity and a rotating reference frame have been explored for structures in a zero gravity environment. A simple yet general approach to modeling was developed, and applied to analyze the dynamics of a specific prototypical structure. The effects of energy dissipation were included and studied in depth for a model problem. Equilibria, bifurcations, and asymptotic stability were analyzed in some carefully chosen examples which capture the essential general features of nonlinear distributed parameter models of rotating elastic structures. GRA

**N87-19755*#** Lockheed Missiles and Space Co., Sunnyvale, Calif.
**PASSIVE STABILIZATION FOR LARGE SPACE SYSTEMS**
J. R. SESAK, M. J. GRONET, and G. M. MARINOS Washington NASA Apr. 1987 140 p
(Contract NAS1-17660)
(NASA-CR-4067; NAS 1.26:4067) Avail: NTIS HC A07/MF A01 CSCL 22B

The optimal tuning of multiple tuned-mass dampers for the transient vibration damping of large space structures is investigated. A multidisciplinary approach is used. Structural dynamic techniques are applied to gain physical insight into absorber/structure interaction and to optimize specific cases. Modern control theory and parameter optimization techniques are applied to the general optimization problem. A design procedure for multi-absorber multi-DOF vibration damping problems is presented. Classical dynamic models are extended to investigate the effects of absorber placement, existing structural damping, and absorber cross-coupling on the optimal design synthesis. The control design process for the general optimization problem is formulated as a linear output feedback control problem via the development of a feedback control canonical form. The techniques are applied to sample micro-g and pointing problems on the NASA dual keel space station. Author

# 07

# POWER

Includes descriptions of analyses, systems, and trade studies of electric power generation, storage, conditioning and distribution.

**A87-12091**
**ULTRATHIN SILICON SOLAR CELL ASSEMBLY TECHNOLOGY**
Y. MATSUI, K. KAMIMURA, K. SAKURAI, S. KAMINISHI, T. MATSUTANI (Sharp Corp., Nara, Japan) et al. (University of Tokyo, Institute of Space and Astronautical Science, Space Energy Symposium, 4th, Tokyo, Japan, Mar. 1, 1985) Space Solar Power Review (ISSN 0191-9067), vol. 5, no. 4, 1985, p. 365-369.

The assembly technology of newly developed ultrathin silicon solar cells was studied. The fundamental technology of welding interconnectors to 50-micron-thick, 2 x 4-cm solar cells, CIC (connector integrated cell) fabrication, module fabrication and of integrating these modules to substrates was developed, and thus the production process was established. In order to verify this production process, testing panels were fabricated and thermal cycling tests were performed. The test results showed that these panels had no visual damage and no electrical degradation. Author

**A87-13437**
**POINTING, CONTROL, AND STABILIZATION OF SOLAR DYNAMIC SYSTEM ON A SPACE STATION**
E. T. FALANGAS and H. H. WOO (Rockwell International Corp., Space Station Systems Div., Downey, CA) IN: 1986 American Control Conference, 5th, Seattle, WA, June 18-20, 1986, Proceedings. Volume 3 . New York, Institute of Electrical and Electronics Engineers, 1986, p. 1563-1571.

This paper presents the design and analysis of a drive system to soft couple the solar dynamic (SD) power systems from interaction with the structure of a single keel Space Station. The drive system features a low bandwidth controller that attenuates the dominant transverse boom torsional mode. The objective is to present some preliminary results. The pointing of the massive SD system is sensitive to induced disturbance forces. Minimizing the effects of these disturbances on SD pointing is essential in achieving desired pointing accuracy. An integral loop is included to attenuate low frequency disturbances. Beside the integration of the two controllers, the viable concept presented in this paper utilizes sun sensors mounted outboard of the alpha joint on the left and right transverse booms. Tracking error is minimized by using the pointing error from the sun in the control logic for alpha drive slewing. The system is capable of achieving good stability robustness, performance, and acceptable disturbance rejection. Author

**A87-15890#**
**CLOSED BRAYTON SOLAR DYNAMIC POWER FOR THE SPACE STATION**
A. A. PIETSCH and S. W. TRIMBLE (Garrett Fluid Systems Co., Tempe, AZ) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p.
(IAF PAPER 86-135)

A 25.75-kWe solar dynamic closed Brayton cycle (CBC) power conversion system, consisting of an offset parabolic concentrator that captures solar rays and focuses concentrated energy into a receiver, is proposed for the Space Station. To increase the efficiency of the power system, a recuperator is employed to transfer waste heat from the turbine discharge stream to the compressor discharge stream. Thermal energy storage in the form of molten salt will provide heat to the engine during eclipse or shadow periods. The single-phase working-fluid system demonstrates low life-cycle costs and minimal maintenance, and the design should reduce aerodynamic drag, thus saving reboost propellants. R.R.

**A87-15891#**

**THE POTENTIAL OF SOLAR DYNAMIC POWER SYSTEMS FOR FUTURE SPACE APPLICATIONS**

U. SPRENGEL (DFVLR, Stuttgart, West Germany) and W. WESTPHAL (Telefunken AG, Wedel, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 25 p.
(IAF PAPER 86-136)

On the basis of projected system requirements for both European and American Space Station concepts, as well as currently foreseen mission requirements, several photovoltaic and solar-dynamic power system concepts are formulated and evaluated with a view to performance and economic feasibility. It is noted that, while the solar-dynamic system allows substantial collector area reductions, and can achieve enhanced operational control and flexibility in energy storage, the optimal matching of thermal energy storage and power conversion systems will remain a daunting task for system designers. O.C.

**A87-15894*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**SPACE POWER DEVELOPMENT IMPACT ON TECHNOLOGY REQUIREMENTS**

J. F. CASSIDY (NASA, Lewis Research Center, Cleveland, OH), T. J. FITZGERALD, R. I. GILJE, and J. D. GORDON (TRW, Inc., Applied Technology Div., Redondo Beach, CA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p.
(IAF PAPER 86-143)

The paper is concerned with the selection of a specific spacecraft power technology and the identification of technology development to meet system requirements. Requirements which influence the selection of a given technology include the power level required, whether the load is constant or transient in nature, and in the case of transient loads, the time required to recover the power, and overall system safety. Various power technologies, such as solar voltaic power, solar dynamic power, nuclear power systems, and electrochemical energy storage, are briefly described. V.L.

**A87-15895#**

**DESIGN AND OPERATION OF A SOLAR ORGANIC RANKINE POWER SYSTEM FOR SPACE**

R. MCKENNA, T. BLAND, and R. RUDEY (Sundstrand Corp., Rockford, IL) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 12 p.
(IAF PAPER 86-144)

A conservative low-temperature approach to meeting the high power levels required for the Space Station is the Solar Dynamic Organic Rankine Cycle (SD-ORC) power generating system. This approach incorporates a mature technology that has been used in terrestrial systems presently in operation and in several space power designs that have been evaluated through the prototypic testing phase of development. This paper describes the SD-ORC System currently being designed for the Space Station and discusses the technology base that supports the proposed design. Author

**A87-15900*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**SPACE POWER - EMERGING OPPORTUNITIES**

H. W. BRANDHORST (NASA, Lewis Research Center, Cleveland, OH) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p.
(IAF PAPER 86-152)

NASA programs directed towards the development of technologies to meet the cost-effective energy needs of future space missions are described. Consideration is given to the space photovoltaic program, which was developed along two paths: one leading to high-performance ultralight weight solar arrays, the other to high output arrays. The space power materials and energy storage technology are discussed, together with the developmental aspects of an advanced solar dynamic power system and its subsystems. Special attention is given to the Nasa SP-100 Advanced Technology Project and the free-piston Stirling engine technology for nuclear power application. I.S.

**A87-15901#**

**SPACE POWER SYSTEMS FOR THE NEXT DECADE**

T. A. DOUGHERTY, G. VAN OMMERING, and H. E. POLLARD (Ford Aerospace and Communications Corp., Palo Alto, CA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 7 p. refs
(IAF PAPER 86-153)

**A87-15903#**

**LIGHT WEIGHT ELECTROSTATIC GENERATOR OF AC POWER FOR AEROSPACE USES**

F. F. CAP (Innsbruck, Universitaet, Austria) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 4 p.
(IAF PAPER 86-155)

It will be shown in this paper that an electrostatic generator is superior to a magnetic generator as far as weight and specific weight is concerned. To compare an electrostatic with a magnetic generator an evaluation of the specific weight of a magnetic generator is presented. The electrostatic generator consists of N+1 rotating circular disks of radius R and thickness d. For vacuum the specific power of the electrostatic engine is 5.15 kW/kg which is better than the value given for the magnetic generator. To prove the principle and the (nonlinear) stabilization of the generator a model has been built. It delivered 1050 V of sinusoidal ac at 350 cycles. Such generators are typical low weight high-frequency high voltage low current generators for uses in the vacuum of cosmic space. Author

**A87-15905#**

**OPPORTUNITIES FOR COMMERCIAL SPACE POWER**

D. N. STITT, R. J. GOSS (General Space Corp., Pittsburgh, PA), and P. E. GLASER (Arthur D. Little, Inc., Cambridge, MA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 7 p.
(IAF PAPER 86-157)

The expansion of space activities in an increasing number of countries and the development of capabilities to pursue these activities are described in relation to emerging opportunities for commerical space power. The evolution of a space industrial infrastructure, based on the development of space stations and platforms that is opening up opportunities for space power projects is described. The need for a viable power supply to service the space infrastructure is stressed. The Space Shuttle, Space Station, and space power - and their relation to the development of a space infrastructure and inherent commercial opportunities - are also described. The policy considerations to enable space mission planning and the development of systems and supporting technologies are cited. Author

**A87-15930*#** Astro Aerospace Corp., Carpinteria, Calif.

**STRUCTURAL CONCEPTS FOR LARGE SOLAR CONCENTRATORS**

J. M. HEDGEPETH (Astro Aerospace Corp., Carpinteria, CA) and R. K. MILLER (Southern California, University, Los Angeles, CA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p. refs
(Contract NAS1-17536)
(IAF PAPER 86-202)

Solar collectors for space use are examined, including both early designs and current concepts. In particular, attention is given to stiff sandwich panels and aluminum dishes as well as inflated and umbrella-type membrane configurations. The Sunflower concentrator is described as an example of a high-efficiency collector. It is concluded that stiff reflector panels are most likely to provide the long-term consistent accuracy necessary for low-orbit operation. A new configuration consisting of a Pactruss backup structure, with identical panels installed after deployment in space,

is presented. It is estimated that concentration ratios in excess of 2000 can be achieved with this concept. V.L.

**A87-16138*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**ELECTRICAL POWER SYSTEM FOR THE U.S. SPACE STATION**

D. L. NORED (NASA, Lewis Research Center, Cleveland, OH) and G. J. HALLINAN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 13 p. Previously announced in STAR as N86-32520.
(IAF PAPER 86-37)

The Space Station Electrical Power System presents many interesting challenges. It will be much larger than previous space power systems, and it must be designed for on-orbit maintenance and replacement, along with having a growth capability. The power generation, energy storage, and power management and distribution (PMAD) subsystems comprise the primary elements of the overall system. Each was analyzed by NASA Lewis Research Center and its two contractors Rocketdyne and TRW - in the definition studies of the program to determine the optimum approach to minimize initial costs and life cycle costs. For the PMAD subsystem, a ring bus architecture operating at 440 V, 20 kHz, single phase, was selected. Photovoltaic and solar dynamic power generation subsystems were both studied. Major tradeoffs were made for each subsystem and for the overall system, and a hybrid system (both photovoltaic and solar dynamic) was selected. Author

**A87-16929*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**POWER IS THE KEYSTONE**

R. L. THOMAS (NASA, Lewis Research Center, Cleveland, OH) Aerospace America (ISSN 0740-722X), vol. 24, Sept. 1986, p. 36-38, 40.

An evaluation is made of the various technologies that have been considered for incorporation into the NASA Space Station's solar power system. A major feature of the system is noted to be the use of both 25 kW capacity of photovoltaic power and two 25-kW turbine-driven generators based on the heating of a working fluid by a mirror concentrator dish. Fuel cells will be used to store excess electrical energy, together with nickel-cadmium batteries. The selection of this manned Space Station power system was arrived at through a comparison of six different configurations. O.C.

**A87-18026**

**IECEC '86; PROCEEDINGS OF THE TWENTY-FIRST INTERSOCIETY ENERGY CONVERSION ENGINEERING CONFERENCE, SAN DIEGO, CA, AUGUST 25-29, 1986. VOLUMES 1, 2, & 3**

Conference sponsored by AChS, SAE, AIAA, et al. Washington, DC, American Chemical Society, 1986, p. Vol. 1, 673 p.; vol. 2, 737 p.; vol. 3, 897 p. For individual items see A87-18027 to A87-18181.

Recent developments in the technology of energy conversion are discussed in reviews and reports. Topics examined include advanced conversion concepts, geothermal conversion, energy policy, pyroelectric conversion materials, large cogeneration systems, coal conversion, biomass energy, rock-fluid interactions, hydrogen energy, and nuclear energy. Consideration is given to heat pumps and engines, MHD conversion, thermal storage, batteries, solar conversion, and power-conversion requirements and technologies for space use. T.K.

**A87-18045**

**THERMAL ENERGY STORAGE FOR ORGANIC RANKINE CYCLE SOLAR DYNAMIC SPACE POWER SYSTEMS**

G. R. HEIDENREICH and M. B. PAREKH (Sundstrand Corp., Rockford, IL) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 2 . Washington, DC, American Chemical Society, 1986, p. 791-797.

An organic Rankine cycle-solar dynamic power system (ORC-SDPS) comprises a concentrator, a radiator, a power conversion unit, and a receiver with a thermal energy storage (TES) subsystem which charges and discharges energy to meet power demands during orbital insolation and eclipse periods. Attention is presently given to the criteria used in designing and evaluating an ORC-SDPS TES, as well as the automated test facility employed. It is found that a substantial data base exists for the design of an ORC-SDPS TES subsystem. O.C.

**A87-18046**

**AN INTEGRATED HEAT PIPE-THERMAL STORAGE DESIGN FOR A SOLAR RECEIVER**

E. KEDDY, J. T. SENA, K. WOLOSHUN, M. A. MERRIGAN (Los Alamos National Laboratory, NM), and G. HEIDENREICH (Sundstrand Corp., Rockford, IL) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 2 . Washington, DC, American Chemical Society, 1986, p. 798-804.

Light-weight heat pipe wall elements that incorporate a thermal storage subassembly within the vapor space are being developed as part of the Organic Rankine Cycle Solar Dynamic Power System (ORC-SDPS) receiver for the Space Station application. The operating temperature of the heat pipe elements is in the 770 to 810 K range with a design power throughput of 4.8 kW per pipe. The total heat pipe length is 1.9 M. The Rankine cycle boiler heat transfer surfaces are positioned within the heat pipe vapor space, providing a relatively constant temperature input to the vaporizer. The heat pipe design employs axial arteries and distribution wicked thermal storage units with potassium as the working fluid. Performance predictions for this configuration have been conducted and the design characterized as a function of artery geometry, distribution wick thickness, porosity, pore size, and permeability. Author

**A87-18048*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.

**MATERIALS COMPATIBILITY ISSUES RELATED TO THERMAL ENERGY STORAGE FOR A SPACE SOLAR DYNAMIC POWER SYSTEM**

N. M. FAGET (NASA, Johnson Space Center, Houston, TX) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 2 . Washington, DC, American Chemical Society, 1986, p. 811-815.

Attention is given to results obtained to date in developmental investigations of a thermal energy storage (TES) system for the projected NASA Space Station's solar dynamic power system; these tests have concentrated on issues related to materials compatibility for phase change materials (PCMs) and their containment vessels' materials. The five PCMs tested have melting temperatures that correspond to the operating temperatures of either the Brayton or Rankine heat engines, which were independently chosen for their high energy densities. O.C.

**A87-18068*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**ELECTRICAL POWER SYSTEM DESIGN FOR THE U.S. SPACE STATION**
D. L. NORED and D. T. BERNATOWICZ (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1416-1422.

The power systems for the Space Station manned core and platforms that have been selected in definition studies are described in this paper. The selected system for the platforms uses silicon arrays and Ni-H2 batteries. The power system for the manned core is a hybrid employing arrays and batteries identical to those on the platform along with solar dynamic modules using either Brayton or organic Rankine engines. The power system requirements, candidate technologies, and configurations that were considered, and the basis for selection, are discussed. Author

**A87-18107*** Life Systems, Inc., Cleveland, Ohio.
**ALKALINE WATER ELECTROLYSIS TECHNOLOGY FOR SPACE STATION REGENERATIVE FUEL CELL ENERGY STORAGE**
F. H. SCHUBERT (Life Systems, Inc., Cleveland, OH), M. A. HOBERECHT, and M. LE (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1617-1627. Research supported by the Life System, Inc. and NASA. refs

The regenerative fuel cell system (RFCS), designed for application to the Space Station energy storage system, is based on state-of-the-art alkaline electrolyte technology and incorporates a dedicated fuel cell system (FCS) and water electrolysis subsystem (WES). In the present study, emphasis is placed on the WES portion of the RFCS. To ensure RFCS availability for the Space Station, the RFCS Space Station Prototype design was undertaken which included a 46-cell 0.93 cu m static feed water electrolysis module and three integrated mechanical components. K.K

**A87-18136**
**ADVANCES IN FLYWHEEL TECHNOLOGY FOR SPACE POWER APPLICATIONS**
M. OLSZEWSKI and D. U. OKAIN (Oak Ridge National Laboratory, TN) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1823-1828. refs
(Contract DE-AC05-84OR-21400)

Power derived from stored energy rather than directly from the primary thermal source is an attractive alternative for SDI sprint power. The Enrichment Technology Applications Center was created to utilize unique enrichment program-based expertise and facilities for applications in other government programs and emerging technologies of national interest. Research and development activities are focused on high-performance flywheel energy storage systems, and early testing has demonstrated high speed capability using carbon composite flywheel rims. The Flywheel Energy Storage Program is aimed at developing a high-performance flywheel energy storage module with a total stored energy of one gigajoule; anticipated operating speed is in the range of 1100-1200 m/s. Author

**A87-18141#**
**THE USE OF NUCLEAR ENERGY FOR BIMODAL APPLICATIONS IN SPACE**
F. L. HORN, J. R. POWELL, and H. LUDEWIG (Brookhaven National Laboratory, Upton, NY) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1849-1853.
(Contract DE-AC02-76CH-00016)

The versatile bimodal nuclear reactor is proposed for producing space station-keeping power of 100's kW and also capable of bursts of power by ramping to 100's MW for short times to operate high power magnetic systems. The particle bed reactor, using half-millimeter diameter fuel particles immersed in coolant, provides the heat transfer capability needed for this power level. The coolant is a gas when directly coupled to a Brayton Cycle and is particularly responsive. The reactor design uses 37 fuel elements in a triangular pattern held in a cylindrical core. The reactor, radiator and turbo-generator are packaged for insertion into the Shuttle cargo bay. Author

**A87-18144**
**DESIGN OF A SUPERCONDUCTING ALTERNATOR FOR SPACE-BASED POWER GENERATION**
R. E. DODGE, JR., E. P. COOMES (Battelle Pacific Northwest Laboratories, Richland, WA), J. L. KIRTLEY, JR., and S. J. MCCABE (MIT, Cambridge, MA) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1869-1874. refs

A study was performed to assess the feasibility of using a superconducting alternator for space power generation and to develop a preliminary machine design. The superconducting alternator consists of a rotor with superconducting field windings and a counter rotating armature with normally conducting helical windings. A unique feature of this design is the counter rotation of the alternator armature which permits balancing of the rotational inertia in the machine so that no torque is applied to the space platform. K.K.

**A87-18147*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**SPACE STATION POWER SYSTEM SELECTION**
R. R. RICE (NASA, Johnson Space Center, Houston, TX) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1886-1891.

The Space Station power system selection process is described with attention given to management organization and technical considerations. A hybrid power system was chosen because of the large life cycle cost savings. The power management and distribution system that was chosen was the 400 Hz system. K.K.

**A87-18149**
**SOLAR ARRAYS FOR SPACE STATION AND PLATFORMS**
R. V. ELMS (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1898-1902.

Current large area solar array technology combined with short term technology advancements can power the initial Space Station and Platforms based on the NASA Phase B Space Station design requirements. This approach provides low schedule, cost, and performance risk for the initial Space Station. This approach also allows the Phase C/D program funding to be shaped to take advantage of the advanced technology status of large area solar arrays. The current approach to IOC Space Station power sources uses a hybrid photovoltaic (PV) - Solar Dynamic (SD) system.

NASA has conducted studies to select the ratio of PV to SD. These studies involve a number of Space Station system variables as well as the closely related energy storage system design. This paper discusses the current and advanced solar array technology which will have application to the Space Station solar arrays. The solar array sizes for supporting different fractions of the IOC Space Station user bus power are presented along with the arrays for the platforms. Potential atomic oxygen protection designs are also presented. Author

**A87-18150*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.

**ALKALINE RFC SPACE STATION PROTOTYPE - 'NEXT STEP SPACE STATION'**

I. M. HACKLER (NASA, Johnson Space Center, Houston, TX) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1903-1908.

The regenerative fuel cell, a candidate technology for the Space Station's energy storage system, is described. An advanced development program was initiated to design, manufacture, and integrate a regenerative fuel cell Space Station prototype (RFC SSP). The RFC SSP incorporates long-life fuel cell technology, increased cell area for the fuel cells, and high voltage cell stacks for both units. The RFC SSP's potential for integration with the Space Station's life support and propulsion systems is discussed. K.K.

**A87-18151**

**SOLAR OPTICS SIMULATION FOR A SPACE STATION SOLAR DYNAMICS POWER SYSTEM**

J. S. ARCHER, E. S. DIAMANT, R. F. KEMP, and J. W. LOCKWOOD (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1909-1914.

This paper discusses the application of the IPAGOS code to guide the design of a solar dynamic (SD) module for the Space Station. Graphical displays are presented illustrating the solar flux distribution on the receiver cavity walls as a function of receiver size, receiver geometry, rim angle, solar misalignment, concentrator mirror tilt, and position on the focal axis. Focal plane distribution of the solar flux is illustrated for the same functions. The relative importance of concentrator mirror error and pointing error is illustrated. The great value of a design tool such as IPAGOS for configuration selection and design optimization is clearly noted. Author

**A87-18152**

**A SPACE STATION POWER MANAGEMENT SYSTEM ARCHITECTURE**

D. K. DECKER and J. F. CAMPBELL (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1915-1918.

This paper describes a distributed power management system architecture for the Space Station and presents the rationale that was used to derive this configuration. The architecture provides sufficient redundancy to be consistent with Space Station reliability requirements and provides an interface to the data management system. The architecture consists of redundant load center controllers, power source controllers for each energy storage channel, electrical power system controllers for overall management of the power subsystem, and parallel data bases for the transport medium. A data bus protocol is presented which is consistent with IEEE standards as well as the International Standards Organization (ISO) model. Trade study results are presented that identify available microprocessors and define processing requirements. Functional requirements are presented along with rationale for partitioning of man-machine roles. Author

**A87-18153**

**A CONCEPT FOR A SPACE STATION COMMON MODULE POWER MANAGEMENT AND DISTRIBUTION SYSTEM**

J. H. MASSON and C. O. PISTOLE (Martin Marietta Corp., Denver, CO) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1919-1923.

The Space Station Common Module will distribute 50 kW of power to subsystem equipment, outfitter equipment, and user payloads. It will have an extended orbital life and must support reconfiguration due to changing equipment mix. Therefore, the Common Module power management and distribution system must be flexible, reliable, and user friendly while achieving program goals of low cost, low volume, and low mass. This paper will identify the supporting requirements needed to achieve these goals, and present a design concept which satisfies them. Modularity and maintainability are key requirements which support an extended on-orbit life and reconfiguration. A flexible design with standard interfaces also supports on-orbit maintenance and reconfiguration. The paper discusses these considerations in detail, and uses them to develop a conceptual power management and distribution system design. Author

**A87-18176**

**SOLAR DYNAMIC POWER FOR SPACE STATION IOC**

E. BINZ and J. HARTUNG (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 2072-2076.

Studies reveal that the application of solar dynamic power to the IOC initial operating capability Space Station in a hybrid configuration combines the strengths of the two types of power generators at competitive IOC cost with substantial life cycle cost savings. Criteria used for evaluating reference concepts included cost and technology development status. Successful demonstration of the receiver/thermal storage coupled with the extensive hardware base in other portions of the system give confidence that solar dynamic power will be available for Space Station IOC. Author

**A87-18182*#** Boeing Aerospace Co., Huntsville, Ala.

**SPACE STATION POWER DISTRIBUTION AND CONTROL**

A. H. WILLIS (Boeing Aerospace Co., Huntsville, AL) AChS, SAE, AIAA, et al., Intersociety Energy Conversion Engineering Conference, 21st, San Diego, CA, Aug. 25-29, 1986, Paper. 13 p. (Contract NAS8-36526)

A general description of the Space Station is given with the basic requirements of the power distribution and controls system presented. The dual bus and branch circuit concepts are discussed and a computer control method presented. Author

**A87-18342*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**THE POTENTIAL IMPACT OF NEW POWER SYSTEM TECHNOLOGY ON THE DESIGN OF A MANNED SPACE STATION**

J. S. FORDYCE and H. J. SCHWARTZ (NASA, Lewis Research Center, Cleveland, OH) IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 1099-1105. Previously announced in STAR as N84-31272. refs

Larger, more complex spacecraft of the future such as a manned Space Station will require electric power systems of 100 kW and more, orders of magnitude greater than the present state of the art. Power systems at this level will have a significant impact on the spacecraft design. Historically, long-lived spacecraft have relied on silicon solar cell arrays, a nickel-cadmium storage battery and

operation at 28 V dc. These technologies lead to large array areas and heavy batteries for a Space Station application. This, in turn, presents orbit altitude maintenance, attitude control, energy management and launch weight and volume constraints. Size (area) and weight of such a power system can be reduced if new higher efficiency conversion and lighter weight storage technologies are used. Several promising technology options including concentrator solar photovoltaic arrays, solar thermal dynamic and ultimately nuclear dynamic systems to reduce area are discussed. Also, higher energy storage systems such as nickel-hydrogen and the regenerative fuel cell (RFC) and higher voltage power distribution which add system flexibility, simplicity and reduce weight are examined. Emphasis placed on the attributes and development status of emerging technologies that are sufficiently developed so that they could be available for flight use in the early to mid 1990's. Author

**A87-18411**
**ANALYTICAL STUDY OF SOLAR RAY SUPPLY SYSTEM WITH LIGHT CONDUCTING CABLE IN SPACE STATION**
N. TANATSUGU, M. YAMASHITA (Tokyo, University, Japan), K. MORI (Keio University, Yokohama, Japan), and K. NITTA (National Aerospace Laboratory, Chofu, Japan) IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 1647-1651.

Some of the experiments planned for the Space Station will require a lot of energy in the original form of the solar ray. In order to meet this requirement, a proposed solar ray supply system is presented. In this paper, analytical study of the solar ray supply system in the Space Station is presented. Author

**A87-19872**
**IN-ORBIT PERFORMANCE OF HUGHES HS 376 SOLAR ARRAYS**
STEVEN W. GELB, LELAND J. GOLDHAMMER, and DANA X. KEROLA (Hughes Aircraft Co., Space and Communications Group, El Segundo, CA) IN: Photovoltaic Specialists Conference, 18th, Las Vegas, NV, October 21-25, 1985, Conference Record . New York, Institute of Electrical and Electronics Engineers, Inc., 1985, p. 362-367. refs

The synchronous orbit performance of Hughes Aircraft Company HS 376 spacecraft solar arrays employing the K7 solar cell is presented and compared with ground-based computer predictions for orbital durations greater than 4 years. The HS 376 spacecraft whose solar array performance is discussed include the Satellite Business Systems SBS F-1, F-2, and F-3; the Telesat Canada Anik C-2, C-3, D-1, and D-2; and the Western Union Westar IV and V. Launch of the first Hughes HS 376 satellite with a K7 solar array, the SBS F-3, occurred on November 15, 1980. A brief description of each solar array and the general methodology for predicting solar array performance are presented. The in-space performance data indicate forward solar array power degradation of 13.2 percent for SBS F-3 after 52 months in orbit, 11.2 percent for Anik C-3 after 28 months in orbit, and 11.7 percent for Anik D-1 after 31 months in orbit. The predicted output of each of these solar arrays is within 2 percent of the actual output as obtained through telemetry. The ability to accurately predict solar array performance within telemetry accuracy is demonstrated. This capability combines the solar array electrical measurements in the as-built configuration, manufacturing consistency, and sound computer modeling techniques. Author

**A87-19877*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**SPACE STATION POWER SYSTEM ISSUES**
A. F. FORESTIERI (NASA, Lewis Research Center, Cleveland, OH) IN: Photovoltaic Specialists Conference, 18th, Las Vegas, NV, October 21-25, 1985, Conference Record . New York, Institute of Electrical and Electronics Engineers, Inc., 1985, p. 403-410. refs

A number of attractive options are available for the Space Station Power System. These include a photovoltaic system or solar dynamic system for power generation, batteries or fuel cells for energy storage and ac or dc for power management and distribution. These options are being explored during the present preliminary design and definition phase of the Space Station Program. Final selections are presently targeted for January 1986. Author

**A87-19878**
**HIGH VOLTAGE SOLAR ARRAY PLASMA PROTECTION TECHNIQUES**
JOHN R. BARTON, WILLIAM G. DUNBAR, and AMY C. REISS (Boeing Aerospace Co., Seattle, WA) IN: Photovoltaic Specialists Conference, 18th, Las Vegas, NV, October 21-25, 1985, Conference Record . New York, Institute of Electrical and Electronics Engineers, Inc., 1985, p. 411-417. refs

Spacecraft power levels have continuously increased since the inception of the Space Age, and this trend will continue into the distant future. Solar arrays requiring 100s of kilowatts are expected by the mid 1990s, and the higher power levels will require voltage levels of 100s if not 1000s of volts. Unfortunately, unprotected solar arrays cannot operate at these high voltages because of the interaction between the solar array and the space plasma. This interaction can cause voltage-charge buildups to the kilovolt level, followed by arc discharges, material damage, and the disruption of spacecraft electronics. Consequently, unprotected solar arrays below altitudes of 10,000 km should be limited to voltages less than 250 V dc, and lower than 150 V dc in some low-altitude orbits. However, high-voltage designs can be used if plasma interaction is significantly reduced by protecting the solar array. Solar array protection concepts are presented, including encapsulation and the addition of zero-potential ground planes. Two concentrator configurations are presented which utilize their inherent structure as ground planes, and planar arrays are presented which utilize encapsulation and ground planes in the form of 'lightning rods', 'chicken wire', and/or conductive grid-pattern coatings. Author

**A87-19886**
**BIFACIAL SPACE SILICON SOLAR CELL**
G. STROBL, C. KASPER, K.-D. RASCH, and K. ROY (Telefunken Elektronik GmbH, Heilbronn, West Germany) IN: Photovoltaic Specialists Conference, 18th, Las Vegas, NV, October 21-25, 1985, Conference Record . New York, Institute of Electrical and Electronics Engineers, Inc., 1985, p. 454-457. refs

A bifacial light sensitive solar cell for use in space solar generators is presented. A bifacial cell is almost transparent for infrared radiation, resulting in a low solar absorptance (0.63 for a bare cell). The operating temperature in space is estimated to be 10-20 C lower than for BSR cells. This advantage holds for both LEO and GEO missions. In addition to the direct sun radiation the bifacial cell converts the albedo radiation reflected by the earth and illuminates the back side of the bifacial cell. This is particularly important for LEO missions. The efficiency of experimental cells, 50 to 180 microns thick, was found to be up to 40 percent higher than for conventional BSFR cells. Author

**A87-21801**
**SPACE NUCLEAR POWER SYSTEMS 1985; PROCEEDINGS OF THE SECOND SYMPOSIUM, ALBUQUERQUE, NM, JAN. 14-16, 1985. VOLUMES 3 & 4**
MOHAMED S. EL-GENK, ED. (New Mexico, University, Albuquerque) and MARK D. HOOVER, ED. (Lovelace Inhalation Toxicology Research Institute, Albuquerque, NM) Symposium organized by the University of New Mexico; Sponsored by American Nuclear Society, Sandia National Laboratories, USAF, et al. Malabar, FL, Orbit Book Co., Inc., 1987. Vol. 3, 192 p.; vol. 4, 218 p. For individual items see A87-21802 to A87-21840.

Papers are presented on the US space nuclear power program, civilian and military applications for nuclear power in space, and the designs, requirements, and costs of space nuclear power missions and systems. Topics discussed include space nuclear reactor fuel and fuel performance, the properties of refractory metal alloys, the development of liquid droplet and heat pipe radiators

for thermal management in space, and systems analysis and testing. Consideration is given to methods for converting thermal energy to useable electrical energy in space, control and power conditioning electronics systems for space applications, reactors and shields, options for space nuclear propulsion, and the safety and reliability of using nuclear reactors in space. I.F.

**A87-21805*** Science Applications International Corp., Albuquerque, N. Mex.

**OPENING UP TO THE FUTURE IN SPACE WITH NUCLEAR POWER**

DAVID BUDEN (Science Applications International Corp., Albuquerque, NM) and JOSEPH ANGELO, JR. (Florida Institute of Technology, Melbourne) IN: Space nuclear power systems 1985; Proceedings of the Second Symposium, Albuquerque, NM, Jan. 14-16, 1985. Volume 3 . Malabar, FL, Orbit Book Co., Inc., 1987, p. 35-41. Research sponsored by the Florida Institute of Technology, NASA, and DOE. refs

The relationship between the exploration of space and the availability of abundant power supplies is discussed. It is proposed that nuclear power will be needed to satisfy the power demands of manufacturing facilities in LEO, and power demands for the year 2000 are projected to be 300 KW(e). The capabilities and development of the Space Station are described; the use of nuclear power for the Station and various reactor location configurations are studied. The power requirements that will be necessary for the development of lunar resource bases and the exploration of Mars and other planets are considered; the advantages of nuclear power are examined. I.F.

**A87-21808*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

**SP-100 MISSIONS OVERVIEW**

RICHARD A. WALLACE (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Space nuclear power systems 1985; Proceedings of the Second Symposium, Albuquerque, NM, Jan. 14-16, 1985. Volume 3 . Malabar, FL, Orbit Book Co., Inc., 1987, p. 53-59. DOE-DOD-NASA-sponsored research. refs

This paper reviews both general and specific mission applications for an SP-100 nuclear power subsystem sized for the 10-kWe to 1000-kWe power range. Military applications are treated in a general manner. Four civil mission applications are treated in more detail. Market projection and mission performance data as a function of power are shown. Author

**A87-22770*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.

**APPLICATIONS OF LOW-EARTH-ORBIT POWER TRANSMISSION**

G. D. ARNDT and E. M. KERWIN (NASA, Johnson Space Center, Houston, TX) Space Power (ISSN 0883-6272), vol. 6, 1986, p. 137-155. refs

The use of low-earth-orbit microwave transmission systems to transfer power between two co-orbiting satellites is investigated. A microwave system with a 20 m antenna and 30 m rectenna over a 5-10 km operating range could have possible applications for transmitting 100 kW of power. Antenna/rectenna trade-off sizings, taper analyses, orbital considerations, and possible uses are discussed. Author

**A87-22771**

**SOLAR POWER SATELLITE CONCEPT REVISITED**

PETER E. GLASER (Arthur D. Little, Inc., Cambridge, MA) Space Power (ISSN 0883-6272), vol. 6, 1986, p. 157-163. refs

The continued evolution of the solar power satellite (SPS) concept is reviewed. The advances in generic technologies applicable to the SPS resulting from the growth of commercial activities in space, the Space Station program and the strategic defense initiative are highlighted. The growing international literature on the SPS is cited to indicate that this concept continues to receive consideration. Significant developments, including photovoltaic and solar dynamic conversion, space experiments to test performance of critical technologies, power distribution subsystems, automation and teleoperators that are advancing the feasibility of the SPS are discussed. The possibility of a return to the moon and uses of lunar resources for SPS construction are mentioned as examples of space missions that will contribute to the buildup of the industrial infrastructure that can be the foundation for SPS development. Author

**A87-23646*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**AUTOMATING THE U.S. SPACE STATION'S ELECTRICAL POWER SYSTEM**

JAMES L. DOLCE and KARL A. FAYMON (NASA, Lewis Research Center, Cleveland, OH) Optical Engineering (ISSN 0091-3286), vol. 25, Nov. 1986, p. 1181-1185. refs

NASA's Lewis Research Center is developing a highly automated system for the generation, storage and distribution of electrical power aboard the projected Space Station. This autonomous power system will employ conventional algorithms, enhanced by expert systems, to schedule power, allocate energy, diagnose causes of failure, propose goals, prepare plans for their implementation, evaluate their consequences, and select optimum plans for their execution. While crew-interactive expert systems will be ready for the initial Space Station, total system autonomy is expected to require additional development time. O.C.

**A87-27180**

**MICROWAVE POWER TRANSMISSION FOR USE IN SPACE**

PETER E. GLASER (Arthur D. Little, Inc., Cambridge, MA) Microwave Journal (ISSN 0026-2897), vol. 29, Dec. 1986, p. 44, 46, 48 (6 ff.). refs

The availability of power for use in space is a key requirement for future space activities. The power levels needed to enable the evolution of a space infrastructure that will support the Space Shuttle, a Space Station and lunar missions are reviewed in this article from an industry point of view. The status of solar and nuclear energy source developments for use in space and power transmission technologies is discussed. Possible mission-specific applications of microwave power transmission are highlighted. Technology development directions for microwave power transmission are summarized and related studies are cited. Author

**A87-29753**

**OPTIMIZATION OF A MICROWAVE-BEAM ENERGY TRANSMISSION CHANNEL [OPTIMIZATSIIA TRAKTA PEREDACHI ENERGII SVCH PUCHKOM]**

B. A. BANKE, S. K. LESOTA, and A. V. RACHNIKOV Radiotekhnika (ISSN 0033-8486), Nov. 1986, p. 17-20. In Russian. refs

The optimization of microwave energy transmission for a satellite solar power system is considered. Attention is given to the achievement of maximum energy transmission efficiency between apertures for a fixed ratio of the maximum power density at the receiving antenna to the power density at its edge. Non-Gaussian directivity patterns with a field-intensity gap at the beam axis are presented which assure high utilization coefficients of the receiving antenna and high levels of transmitted power. B.J.

**N87-10173** Virginia Polytechnic Inst. and State Univ., Blacksburg.

**MODELING AND ANALYSIS OF SPACECRAFT POWER SYSTEMS Ph.D. Thesis**

B. H. CHO 1985 187 p

Avail: Univ. Microfilms Order No. DA8605436

A Comprehensive large-scale power system modeling is developed to facilitate the design and analysis of present and future spacecraft power systems. A two-port coupling method is utilized to provide a modularity in model building and analysis of the system. The modular approach allows the model to be flexible, verifiable and computationally efficient. A methodology for the system level analysis is presented with the ability to focus on the performance characteristics of an arbitrary component or

subsystem. The system performance parameters are derived explicitly in terms of the two-port hybrid g-parameter representation of the component or system, and impedances of its terminating subsystems. For this, the stability of the system is analytically determined and the subsystem interaction criteria is observed. Also presented is a model development from the empirical data employing the curve fitting technique. The technique is especially powerful for large scale system modeling and analysis where certain components and subsystems are viewed as black boxes with measurable terminal characteristics. The technique can also be used to realize a reduced order model of a complex subsystem. The Direct Energy Transfer (DET) spacecraft power system is modeled to demonstrate the versatility of the comprehensive system model by performing various D.C. small-signal and large-signal analyses. Dissert. Abstr.

**N87-10904#** London Univ. (England). Queen Mary Coll.
**THE EFFECT OF THE NON-UNIFORM STRESS DISTRIBUTION IN THE BLANKETS OF SINGLE AND TWIN BOOM SOLAR ARRAY PANELS UPON THEIR MODAL CHARACTERISTICS**
J. R. WRIGHT *In* ESA Proceedings of an International Conference on Spacecraft Structures p 125-130 Apr. 1986
Avail: NTIS HC A19/MF A01

The modal behavior of deployed flexible solar arrays of the single boom fold-out and twin boom roll-out types was studied with simple theoretical model configurations. The effect of the nonuniform stress distribution in the array blanket arising from flexible end members was investigated for out-of-plane/bending modes. It is found that the string-like modes important for control are hardly affected so a uniform tension analysis is adequate. However, other modes needed for response behavior are affected, particularly for the single boom array where buckling can occur. It is also found that bending stiffness in the blanket needs to be included to lead to a unique and complete set of array modes if uniform tension is assumed. ESA

**N87-11075*#** Ford Aerospace and Communications Corp., Palo Alto, Calif.
**ENERGY STORAGE SYSTEMS COMPARISON FOR THE SPACE STATION**
G. VANOMMERING *In* NASA. Goddard Space Flight Center The 1985 Goddard Space Flight Center Battery Workshop (date) p 31 - 40 Sep. 1986
Avail: NTIS HC A19/MF A01 CSCL 10C

An overview of the requirements, options, selection criteria and other considerations, and current status with regard to the energy storage subsystem (ESS) for the photovoltaic power system alternative for the space station is provided. Author

**N87-11101*#** Ford Aerospace and Communications Corp., Palo Alto, Calif.
**NICKEL-HYDROGEN BATTERIES FROM INTELSAT 5 TO SPACE STATION**
G. VANOMMERING and A. Z. APPLEWHITE *In* NASA. Goddard Space Flight Center The 1985 Goddard Space Flight Center Battery Workshop (date) p 387 - 397 Sep. 1986
Avail: NTIS HC A19/MF A01 CSCL 10C

The heritage of the Ni-H2 technology that makes the space station application feasible is discussed. It also describes a design for a potential space station Ni-H2 battery system. Specific design values presented here were developed by Ford Aerospace as part of the Rocketdyne team effort on the Phase B Definition and Preliminary Design of the Space Station Power System in support of NASA Lewis Research Center. Author

**N87-12606*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**ADVANCED SOLAR DYNAMIC SPACE POWER SYSTEMS PERSPECTIVES, REQUIREMENTS AND TECHNOLOGY NEEDS**
M. O. DUSTIN, J. M. SAVINO, D. E. LACY, R. P. MIGRA (Sverdrup Technology, Inc., Arnold Air Force Station, Tenn.), A. J. JUHASZ, and C. E. COLES 1986 30 p Proposed for presentation at the Solar Energy Conference, Honolulu, Hawaii, 22-23 Mar. 1987; sponsored by ASME, JSME and JSES
(NASA-TM-88884; E-3292; NAS 1.15:88884) Avail: NTIS HC A03/MF A01 CSCL 10B

Projected NASA, Civil, Commercial, and Military missions will require space power systems of increased versatility and power levels. The Advanced Solar Dynamic (ASD) Power systems offer the potential for efficient, lightweight, survivable, relatively compact, long-lived space power systems applicable to a wide range of power levels (3 to 300 kWe), and a wide variety of orbits. The successful development of these systems could satisfy the power needs for a wide variety of these projected missions. Thus, the NASA Lewis Research Center has embarked upon an aggressive ASD reserach project under the direction of NASA's Office of Aeronautics and Space Technology (OAST). The project is being implemented through a combination of in-house and contracted efforts. Key elements of this project are missions analysis to determine the power systems requirements, systems analysis to identify the most attractive ASD power systems to meet these requirements, and to guide the technology development efforts, and technology development of key components. Author

**N87-12999#** Los Alamos National Lab., N. Mex.
**INTEGRATED HEAT PIPE-THERMAL STORAGE DESIGN FOR A SOLAR RECEIVER**
E. S. KEDDY, J. T. SENA, K. WOLOSHUN, M. A. MERRIGAN, and G. HEIDENREICH (Sundstrand Corp., Rockford, Ill.) 1986 8 p Presented at the Intersociety Energy Conversion Engineering Conference, San Diego, Calif., 25 Aug., 1986
(Contract W-7405-ENG-36)
(DE86-011235; LA-UR-86-1840; CONF-860810-5) Avail: NTIS HC A02/MF A01

Light-weight heat pipe wall elements that incorporate a thermal storage subassembly within the vapor space are being developed as part of the Organic Rankine Cycle Solar Dynamic Power Systems (ORC-SDPS) receiver for the space station application. The operating temperature of heat pipe elements is in the 770 to 810°K range with a design power throughput of 4.8 kW per pipe. The total heat pipe length is 1.9 M. The Rankine cycle boiler heat transfer surfaces are positioned within the heat pipe vapor space, providing a relatively constant temperature input to the vaporizer. The heat pipe design employs axial arteries and distribution wicked thermal storage units with potassium as the working fluid. Stainless steel is used as the containment tube and screen material. Performance predictions for this configuration have been conducted and the design characterized as a function of artery geometry, distribution wick thickness, porosity, pore size, and permeability. Details of the analysis and of fabrication and assembly procedures are presented. DOE

**N87-15267*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**ELECTRICAL POWER SYSTEM DESIGN FOR THE US SPACE STATION**
DONALD L. NORED and DANIEL T. BERNATOWICZ 29 Aug. 1986 19 p Presented at the 21st Intersociety Energy Conversion Engineering Conference, San Diego, Calif., 25-29 Aug. 1986; cosponsored by ACS, SAE, ANS, ASME, IEEE, AIAA and AIChE
(NASA-TM-88824; E-3073; NAS 1.15:88824) Avail: NTIS HC A02/MF A01 CSCL 22B

The multipurpose, manned, permanent space station will be our next step toward utilization of space. A multikilowatt electrical power system will be critical to its success. The power systems for the space station manned core and platforms that have been selected in definition studies are described. The system selected for the platforms uses silicon arrays and Ni-H2 batteries. The

power system for the manned core is a hybrid employing arrays and batteries identical to those on the platform along with solar dynamic modules using either Brayton or organic Rankine engines. The power system requirements, candidate technologies, and configurations that were considered, and the basis for selection, are discussed. Author

**N87-15270*#** Ford Aerospace and Communications Corp., Palo Alto, Calif.
**SPACE STATION EXPERIMENT DEFINITION: ADVANCED POWER SYSTEM TEST BED Final Report**
H. E. POLLARD and R. E. NEFF 15 Dec. 1986 148 p
(Contract NAS3-24664)
(NASA-CR-179502; NAS 1.26:179502; WDL-TR10939) Avail: NTIS HC A07/MF A01 CSCL 10B

A conceptual design for an advanced photovoltaic power system test bed was provided and the requirements for advanced photovoltaic power system experiments better defined. Results of this study will be used in the design efforts conducted in phase B and phase C/D of the space station program so that the test bed capabilities will be responsive to user needs. Critical PV and energy storage technologies were identified and inputs were received from the idustry (government and commercial, U.S. and international) which identified experimental requirements. These inputs were used to develop a number of different conceptual designs. Pros and cons of each were discussed and a strawman candidate identified. A preliminary evolutionary plan, which included necessary precursor activities, was established and cost estimates presented which would allow for a successful implementation to the space station in the 1994 time frame. Author

**N87-16024*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**SOLAR DYNAMIC POWER SYSTEMS FOR SPACE STATION**
THOMAS B. IRVINE, MARSHA M. NALL, and ROBERT C. SEIDEL *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 149-166 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 14B

The Parabolic Offset Linearly Actuated Reflector (POLAR) solar dynamic module was selected as the baseline design for a solar dynamic power system aboard the space station. The POLAR concept was chosen over other candidate designs after extensive trade studies. The primary advantages of the POLAR concept are the low mass moment of inertia of the module about the transverse boom and the compactness of the stowed module which enables packaging of two complete modules in the Shuttle orbiter payload bay. The fine pointing control system required for the solar dynamic module has been studied and initial results indicate that if disturbances from the station are allowed to back drive the rotary alpha joint, pointing errors caused by transient loads on the space station can be minimized. This would allow pointing controls to operate in bandwidths near system structural frequencies. The incorporation of the fine pointing control system into the solar dynamic module is fairly straightforward for the three strut concentrator support structure. However, results of structural analyses indicate that this three strut support is not optimum. Incorporation of a vernier pointing system into the proposed six strut support structure is being studied. Author

**N87-18419#** Brookhaven National Lab., Upton, N. Y.
**USE OF NUCLEAR ENERGY FOR BIMODAL APPLICATIONS IN SPACE**
F. L. HORN, J. R. POWELL, and H. LUDEWIG 1986 6 p
Presented at the Intersociety Energy Conversion Engineering Conference, San Diego, Calif., 25 Aug. 1986
(Contract DE-AC02-76CH-00016)
(DE86-014124; BNL-38312; CONF-860810-19) Avail: NTIS HC A02/MF A01

The versatile bimodal nuclear reactor is proposed for producing space station-keeping power of 100's kW and also capable of bursts of power by ramping to 100's MW for short times to operate high power magnetic systems. The particle bed reactor, using half-millimeter diameter fuel particles immersed in coolant, provides the heat transfer capability needed for this power level. The coolant is a gas when directly coupled to a Brayton Cycle and is particularly responsive. The reactor design uses 37 fuel elements in a triangular pattern held in a cylindrical core. The reactor, radiator and turbo-generator are packaged for insertion into the shuttle cargo bay. DOE

# 08

## ELECTRONICS

Includes descriptions of analytical techniques, analyses, systems, and requirements for internal and external communications, electronics, sensors for position and systems monitoring and antennas.

**A87-13433*** Vigyan Research Associates, Inc., Hampton, Va.
**NONLINEAR ATTITUDE CONTROL OF ELASTIC SPACECRAFT-ANTENNA SYSTEM**
S. N. SINGH (Vigyan Research Associates, Inc., Hampton, VA) IN: 1986 American Control Conference, 5th, Seattle, WA, June 18-20, 1986, Proceedings. Volume 3 . New York, Institute of Electrical and Electronics Engineers, 1986, p. 1539-1544. refs
(Contract NAS1-17919)

An approach to large angle rotational maneuvers of a spacecraft-beam-tip body (an antenna or a reflector) configuration based on nonlinear invertibility and linear feedback stabilization is presented. A control law u sub d is derived to obtain independent decoupled control of attitude angles, lateral elastic deflections, slopes due to bending and angular deflection due to torsion at the tip of the beam using torquers and force actuators. For the stabilization of the elastic oscillations, a linear feedback control law, u sub s, is obtained based on a linearized model about the terminal state augmented with a servo-compensator. Simulation results obtained for single axis control, for simplicity, show that large slewing and elastic mode stabilization can be accomplished in spite of uncertainty in the system using the total control u = u sub d + u sub s. Author

**A87-13710*** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**APPLICATION OF EXPERT SYSTEMS IN THE COMMON MODULE ELECTRICAL POWER SYSTEM**
D. J. WEEKS (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Space station automation; Proceedings of the Meeting, Cambridge, MA, September 17, 18, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1985, p. 35-39. refs

Each Common Module (CM) of the Space Station must be capable of handling a 50 kW electricity supply, 25 kW for transmission and 25 kW for consumption. The power must be handled and managed by on-board systems, a necessity that dovetails with the objectives of Public Law 98-371, which mandates that the Space Station push the state of the art of automation and AI. Expert systems will be needed to handle the large data flow for the power system and to ensure that the system degrades gracefully. Features of the first expert systems expected for the power system, i.e., a dynamic load planner/scheduler and energy storage subsystem management, fault diagnosis/analysis, health status/trend analysis, and orbital replacement advisor expert systems, are described. Finally, growth Space Station expert systems applications are discussed. M.S.K.

**A87-13711*** Lockheed Engineering and Management Services Co., Inc., Houston, Tex.
**AUTOMATIC PROCEDURES GENERATOR FOR ORBITAL RENDEZVOUS MANEUVER**
W. KOHN, J. A. VAN VALKENBURG, and C. K. DUNN (Lockheed Engineering and Management Services Co., Inc., Houston, TX) IN: Space station automation; Proceedings of the Meeting, Cambridge, MA, September 17, 18, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1985, p. 40-52. refs
(Contract NAS9-15800)

This paper describes the development of an expert system for defining and dynamically updating procedures for an orbital rendezvous maneuver. The product of the expert system is a procedure represented by a Moore automaton. The construction is recursive and driven by a simulation of the rendezvousing bodies. Author

**A87-15807#**
**HIGHLY PRECISE THREE-DIMENSIONAL MEASUREMENTS OF COOPERATIVE TARGETS IN THE SHORT RANGE WITH AN OPTICAL SENSOR SYSTEM**
R. LUTZ (Messerschmitt-Boelkow-Blohm GmbH, Munich, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 7 p.
(IAF PAPER 86-08)

The development of an optoelectronic sensor system for highly precise measurements of position and attitude of cooperative targets is described. Three different approaches for the design of the optical sensor system, lidar-system, a camera system, and a position sensitive device (PSD), are evaluated and the advantages of the PSD system are discussed. The sensor system requirements include: discrimination of several target markings, distinction against background illumination, simultaneous measurement of all target markings, appropriate update rate, and high resolution and accuracy. I.F.

**A87-15819#**
**S BAND 3.5-M-DIAMETER FAN RIB TYPE DEPLOYABLE MESH ANTENNA FOR SATELLITE USE**
T. ITANAMI, M. MINOMO, and I. OHTOMO (Nippon Telegraph and Telephone Public Corp., Electrical Communications Laboratories, Yokosuka, Japan) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p. refs
(IAF PAPER 86-28)

A design is presented for a satellite-borne S-band fan rib type deployable mesh antenna for the Japanese maritime satellite communication system. The system proposed here uses an offset Cassegrain antenna with a main reflector focal length of 2.5 m, a subreflector focal length of 450 mm, and a subreflector eccentricity of 2.5. The subreflector angular aperture, as determined by the current distribution method, is 48 degrees, which is about 40 percent larger than the aperture determined by geometrical optics without allowance for the finite aperture edge. The design provides a beam edge gain of more than 31 dB. Details of the structural, electrical, and thermal design of the antenna are examined. V.L.

**A87-15847*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**SPACE STATION COMMUNICATIONS SYSTEM DESIGN AND ANALYSIS**
J. E. RATLIFF (NASA, Johnson Space Center, Houston, TX) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p.
(IAF PAPER 86-68)

Attention is given to the methodologies currently being used as the framework within which the NASA Space Station's communications system is to be designed and analyzed. A key aspect of the CAD/analysis system being employed is its potential growth in size and capabilities, since Space Station design requirements will continue to be defined and modified. The Space Station is expected to furnish communications between itself and astronauts on EVA, Orbital Maneuvering Vehicles, Orbital Transfer Vehicles, Space Shuttle orbiters, free-flying spacecraft, coorbiting platforms, and the Space Shuttle's own Mobile Service Center. O.C.

**A87-15929#**
**A NEW STRUCTURE TOWARD HIGH PRECISION LARGE ANTENNA**
T. YASAKA, M. MINOMO, and K. OHATA (Nippon Telegraph and Telephone Public Corp., Electrical Communications Laboratories, Yokosuka, Japan) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 10 p.
(IAF PAPER 86-201)

A new structure for a large precision antenna is considered, and the concept is demonstrated. This structure copes with the problems related to distortion assessment with increasing flexibility under 1 G, and to thermal deformation suppression over large areas with limited structural mass and volume. In the structure, near-zero truss elements are assembled to a base structure from which a thin paraboloidal shell is supported by a number of support elements with adjustment capability. The structural model of the truss-shell reflectors were fabricated, and tests showed that they possessed the desired structural properties. C.D.

**A87-15934#**
**CONCEPT OF TENSION ACTIVATED CABLE LATTICE ANTENNA**
K. MIURA (Tokyo, University, Japan) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 10 p.
(IAF PAPER 86-206)

A new concept of a three-dimensional, integrated cable lattice system which can meet a variety of requirements concerning facet sizing and arrangement is presented. The geometric modelling of the lattice, the boundary restraints, the reflector surface deviation, and the electromagnetic behavior of the tension truss antenna are discussed. The primary feature of the antenna is that its shape is uniquely determined by the member lengths and their arrangement, and not by the equilibrium of forces. C.D.

**A87-15939#**
**STRESS AND DEFORMATION ANALYSIS OF THERMALLY LOADED LIGHT WEIGHT COMPOSITE STRUCTURES**
K. PFEIFER and J. BODE (Messerschmitt-Boelkow-Blohm GmbH, Muenich, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 16 p.
(IAF PAPER 86-212)

The effect of thermally induced deformations and stresses on the dimensional stability of fiber composite structures is discussed with particular reference to the reflector shells of a space antenna consisting of two Kevlar/Nomex sandwich shells approximately 1100 mm in diameter, their edges connected by a Kevlar/glass ring. The rear shell is fixed at the satellite by a conical carbon fiber composite cylinder and stiffened by four Kevlar/Nomex ribs. A finite-element model is used to determine the contour changes due to different Young's moduli and thermal expansion coefficients of the core. V.L.

**A87-15940#**
**INFLUENCE OF DEFECTS ON DIMENSIONAL STABILITY**
G. REIBALDI (ESA, Mechanical Systems Div., Noordwijk, Netherlands), P. CORDERO, R. GARCIA (Construcciones Aeronauticas, S.A., Madrid, Spain), M. MARCHETTI (Roma, Universita, Rome, Italy), G. MANNARA (Napoli, Universita, Naples, Italy) et al. IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p.
(Contract ESA-5263/82/NL/GM)
(IAF PAPER 86-213)

An experimental study has been carried out to investigate the effect of macroscopic structural defects on the dimensional stability of a composite reflector antenna. In particular, attention is given to delamination and debonding between the CFRP skins and the honeycomb core. The effect of defects on the thermal distortion of the sandwich structure is estimated both qualitatively and quantitatively. Preliminary results indicate that the defects may be

critical for applications where the dimensional stability of the structure has to be kept within microns. V.L.

**A87-16842**

**THE PICON REAL-TIME EXPERT SYSTEM TOOL**

D. LEINWEBER and D. CARLETON (LISP Machines, Inc., Los Angeles, CA) IN: NAECON 1986; Proceedings of the National Aerospace and Electronics Conference, Dayton, OH, May 19-23, 1986. Volume 4 . New York, Institute of Electrical and Electronics Engineers, 1986, p. 1198-1210. refs

The requirements for real-time expert systems in aerospace environments are discussed and illustrated with the Process Intelligent Control (PICON) system. Emphasis is placed on the demands of expanding Space Station operations. The PICON user interface includes icons, for defining schematics for the process to be controlled. LISP-based rules are chosen from an icon menu by using a mouse to point and click or by text entry. Applications of expert systems include controlling satellite electrical power, attitude control, station keeping and propulsion systems and space manufacturing processes. M.S.K.

**A87-18130**

**COMMON MODULE DYNAMIC PAYLOAD SCHEDULER EXPERT SYSTEM**

R. A. TOUCHTON (Technology Applications, Inc., Jacksonville, FL) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1785-1790.

Technology Applications, Inc. (TAI) has developed an expert system demonstration prototype designed to dynamically schedule and reschedule experiments and other payloads aboard the Space Station Common Module. The purpose of this paper is to present the problem domain, development methodology, and technical approach of the Space Station Experiment Scheduler (SSES). Scheduling/rescheduling is performed according to multiple real-world constraints, including power and personnel availability as well as time. Author

**A87-22363#**

**OPTIMAL STRUCTURAL DESIGN WITH CONTROL GAIN NORM CONSTRAINT**

N. S. KHOT, V. B. VENKAYYA (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH), H. OZ (Ohio State University, Columbus), R. V. GRANDHI (Wright State University, Dayton, OH), and F. E. EASTEP (Dayton, University, OH) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 11 p. refs (AIAA PAPER 87-0019)

A structure/control system optimization problem has been formulated with constraints on the closed-loop eigenvalue distribution, structural frequencies and the minimum Frobenious norm of the required control gains. A simultaneous optimization is suggested, where at each iteration control objective function is minimized first with the closed-loop eigenvalue constraints; and then structural optimization is performed to satisfy the constraints on the optimal control gain norm and structural frequencies. The feasibility of the approach is demonstrated on a 2-Bar truss structure. For each locally optimal design, response simulations were done and control efforts were observed. Qualitative aspects of the optimal designs are also included. Author

**A87-23986#**

**WAVE-ABSORBING CONTROLLERS FOR A FLEXIBLE BEAM**

A. H. VON FLOTOW and B. SCHAEFER (DFVLR, Oberpfaffenhofen, West Germany) (Guidance, Navigation and Control Conference, Snowmass, CO, Aug. 19-21, 1985, Technical Papers, p. 443-452) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 9, Nov.-Dec. 1986, p. 673-680. Previously cited in issue 22, p. 3238, Accession no. A85-45924. refs

**A87-24049*** Vigyan Research Associates, Inc., Hampton, Va.

**NONLINEAR ATTITUDE CONTROL OF FLEXIBLE SPACECRAFT UNDER DISTURBANCE TORQUE**

SAHJENDRA N. SINGH (Vigyan Research Associates, Inc., Hampton, VA) Acta Astronautica (ISSN 0094-5765), vol. 13, Aug. 1986, p. 507-514. refs
(Contract NAS1-17919)

A control law for large-angle single-axis rotational maneuvers of a spacecraft-beam-tip body (an antenna or a reflector) configuration is presented. It is assumed that an unknown but bounded disturbance torque is acting on the spacecraft. A model reference adaptive torque control law is derived for the slewing of the space vehicle. This controller includes a dynamic system in the feedback path and requires only attitude angle and rate of the space vehicle for feedback. For damping out the elastic motion excited by the slewing maneuver, a stabilizer is designed assuming that a torquer and a force actuator are available at the tip body. The stabilizer uses only the flexible modes for the synthesis of the control law. Simulation results are presented to show that fast, large-angle rotational maneuvers can be performed using the adaptive controller and the stabilizer in spite of the presence of continuously acting unknown torque on the spacecraft. Author

**A87-25700**

**RECTENNA COMPOSED OF A CIRCULAR MICROSTRIP ANTENNA**

KIYOHIKO ITOH, TAKEO OHGANE, and YASUTAKA OGAWA (Hokkaido University, Sapporo, Japan) (Institute of Electronics and Communications Engineers of Japan, IEEE, and URSI, International Symposium on Antennas and Propagation /ISAP '85/, Kyoto, Japan, Aug. 20-22, 1985) Space Power (ISSN 0883-6272), vol. 6, no. 3, 1986, p. 193-198.
(Contract MOESC-56460102)

One of the big problems in the SPS system is reradiation of the harmonic waves generated by the rectifying diode. The use of a circular microstrip antenna (CMSA) is proposed as a solution, since the CMSA has no higher resonance-harmonic which is an integer multiple of the dominant resonance frequency. However, characteristics of a large rectenna array of CMSAs have not been clarified. This paper is concerned with the absorption efficiency of the rectenna composed of the CMSA. The efficiency is estimated explicitly using an infinite array model. The results show that the absorption efficiency of the infinite rectenna array composed of the CMSA is 100 percent. Also, this paper considers the effect of the losses of the CMSA. Author

**A87-25758**

**THE ROLE OF EXPERT SYSTEMS ON SPACE STATION**

D. R. SLOGGETT (Software Sciences, Ltd.; Environmental and Space Systems Group, Farnborough, England) IN: Space Tech '86; Proceedings of the International Conference, Geneva, Switzerland, May 14-16, 1986 . London, Online International, Ltd., 1986, p. 91-107. refs

The planned deployment of the Space Station, and its associated orbital infrastructure, repreents a unique opportunity to evaluate the potential of expert systems to assist in increasing the autonomy, productivity and effectiveness of the Space Station. This paper seeks to address what current technology can provide to achieve this aim, and highlights previous practical examples of Space AI Systems. The paper makes suggestions for practical research programs, that require urgent attention, to pave the way and demonstrate capability in areas of relatively new technology. From this base the paper suggests some practical areas where AI technology can be applied to the Space Station and their resulting benefits. Specific attention is drawn to the application of expert systems to planning and scheduling and the application of expert monitoring systens to assist in fault diagnosis and repair. The paper concludes that urgent attention is required in the area of demonstration programs where low-risk state-of-the-art developments can be undertaken resulting in very real benefits to the Space Station system. Author

**A87-25759**

**SPACE STATION - THE USE OF EXPERT SYSTEMS FOR PLANNING**

JENS GULDBERG and JENS LANGELAND (Computer Resources International A/S, Denmark) IN: Space Tech '86; Proceedings of the International Conference, Geneva, Switzerland, May 14-16, 1986 . London, Online International, Ltd., 1986, p. 109-117. refs

Expert systems have been shown to provide useful techniques for handling planning problems related to the operation of complex systems and to system engineering. A brief review of the principle features of such planning systems is used as a reference for a discussion on relevant applications for the Space Station, which include, e.g., mission planning, scheduling of maintenance, software development, payload design, and check-out procedures. Author

**A87-26636**

**FIBER OPTIC LINK FOR SPACE COMMUNICATION APPLICATION**

S. A. SIEGEL, J. C. BARONI (RCA David Sarnoff Laboratories, Princeton, NJ), E. DIRUSSO (RCA, Communications and Information Systems Div., Camden, NJ), and P. R. HERCZFELD (Drexel University, Philadelphia, PA) IN: Optical technologies for communication satellite applications; Proceedings of the Meeting, Los Angeles, CA, Jan. 21, 22, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 239-246. Research supported by RCA and Commonwealth of Pennsylvania's Ben Franklin Partnership. refs

Primary considerations in complex space-based communications system designs encompass optimal size, weight, bandwidth, and crosstalk of components and subsystems. Attention is presently given to the advantages of optoelectronic systems (which include low weight, broad bandwidth, and excellent crosstalk isolation) over those employing coaxial cables in the case of a satellite or space station equipped with microwave receivers and transmitters operating in the 10 to 40 GHz range. A distribution network is designed which can route communication signals between receivers and transmitters. The performance of a 750-MHz bandwidth optical link is characterized in terms of frequency response, intermodulation distortion, noise, and power budget. O.C.

**A87-27948*#** Virginia Polytechnic Inst. and State Univ., Blacksburg.

**EFFECT OF SENSOR AND ACTUATOR ERRORS ON STATIC SHAPE CONTROL FOR LARGE SPACE STRUCTURES**

RAPHAEL T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg) and HOWARD M. ADELMAN (NASA, Langley Research Center, Hampton, VA) AIAA Journal (ISSN 0001-1452), vol. 25, Jan. 1987, p. 134-138. Previously announced in STAR as N85-29998. refs

An analytical study was performed to predict and assess the effect of actuator and sensor errors on the performance of a shape control procedure for flexible space structures using applied temperatures. Approximate formulas were derived for the expected value and variance of the rms distortion ratio (ratio of rms distortions with and without corrections) based on the assumption of zero-mean normally distributed random errors in measured distortions and actuator output temperatures. Studies were carried out for a 55-meter radiometer antenna reflector distorted from its ideal parabolic shape by nonuniform orbital heating. The first study consisted of varying the sensor and actuator errors for the case of 12 actuators and computing the distortion ratio. In the second study, sensor and actuator errors were prescribed and the effect of increasing the number of actuators was evaluated. Author

**A87-30891**

**COMMUNICATIONS SPACECRAFT**

SAMUEL W. FORDYCE IN: Space science and applications: Progress and potential . New York, IEEE Press, 1986, p. 201-213.

Progress in the designs and performance capabilities of communications satellites is traced from the Echo 1 Al-coated mylar balloon in 1960 to systems planned for the 1990s and beyond. The services allowed with the passive balloon concept were too limited and led to Telstar spacecraft, with 600 voice channels, being placed in elliptical orbits. Geosynchronous communications began in 1963 with the Syncom satellite, which also carried television signals. The evolution of subsequent Intelsat and ANIK satellites is described, as are features of the Marisat, Marecs, and the DBS systems. The near-term capabilities for DBS, advanced communications satellites using TDMA techniques, and mobile communications systems are summarized, along with the NASA ACTS and MSAT-X satellites for exploring the necessary technologies. The roles the Space Station and unmanned GEO platforms will play in future satellite communications are discussed. M.S.K.

**A87-30893*** National Aeronautics and Space Administration, Washington, D.C.

**COMMUNICATIONS TECHNOLOGY**

C. LOUIS CUCCIA (NASA, Washington, DC) and JOSEPH SIVO IN: Space science and applications: Progress and potential . New York, IEEE Press, 1986, p. 227-250.

The technologies for optimized, i.e., state of the art, operation of satellite-based communications systems are surveyed. Features of spaceborne active repeater systems, low-noise signal amplifiers, power amplifiers, and high frequency switches are described. Design features and capabilities of various satellite antenna systems are discussed, including multiple beam, shaped reflector shaped beam, offset reflector multiple beam, and mm-wave and laser antenna systems. Attitude control systems used with the antenna systems are explored, along with multiplexers, filters, and power generation, conditioning and amplification systems. The operational significance and techniques for exploiting channel bandwidth, baseband and modulation technologies are described. Finally, interconnectivity among communications satellites by means of RF and laser links is examined, as are the roles to be played by the Space Station and future large space antenna systems. M.S.K.

**N87-10172*#** Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechancis.

**IDENTIFICATION AND CONTROL OF STRUCTURES IN SPACE Progress Report, 1 Jul. - 31 Dec. 1985**

L. MEIROVITCH 1985 42 p
(Contract NAG1-225)
(NASA-CR-179811; NAS 1.26:179811) Avail: NTIS HC A03/MF A01 CSCL 22B

Work during the period July 1 - December 31, 1985, has concentrated on the application of the equations derived in the preceding period to the maneuvering and vibration suppression of the Spacecraft Control Laboratory Experiment (SCOLE) model. Two different situations have been considered: (1) a space environment and (2) a laboratory environment. This report covers the first case and consists of a paper entitled Maneuvering and Vibration Control of Flexible Spacecraft, presented at the Workshop on Structural Dynamics and Control Interaction of Flexible Structures, Marshall Space flight Center, Huntsville, AL, April 22 to 24, 1986. The second case will be covered in the report for the next period. Author

**N87-10903#** Footscray Inst. of Tech. (Australia).

**ON A SIMPLE VIBRATION CONTROL DESIGN FOR LARGE SPACE STRUCTURE MODELS WITH UNCERTAIN PARAMETERS**

R. LICATA *In* ESA Proceedings of an International Conference on Spacecraft Structures p 119-124 Apr. 1986
Avail: NTIS HC A19/MF A01

The presence of unavoidable modeling errors and sizeable uncertainty in parameters of a reduced-order model of a large flexible space structure is addressed in relation to the controller design problem. Due mainly to limitations placed by on-board computers (which cause on-line adaptive or self-tuning control schemes to become unrealizable on flexible spacecraft) a controller design solution in the form of a simple to implement time-invariant feedback, obtained by considering constant and with known statistics the uncertain model parameters, is presented. The

proposed stochastic optimal control scheme, more insensitive to parameter variation and spillover effects compared with that obtained by deterministic approach, may be used in the design of local or global controllers of a flexible spacecraft structure. ESA

**N87-11762*#** TRW Defense and Space Systems Group, Redondo Beach, Calif.
**MICROCOMPUTER DESIGN AND ANALYSIS OF THE CABLE CATENARY LARGE SPACE ANTENNA SYSTEM**
W. AKLE *In* NASA. Langley Research Center Recent Experiences in Multidisciplinary Analysis and Optimization, Part 2 14 p 1984
Avail: NTIS HC A22/MF A01 CSCL 20K

The use of microcomputers in the design of a cable catenary large space antenna system is discussed. The development of a system design capability, data base utilization, systems integration, program structure and logic, and integrated graphics output are discussed. R.J.F.

**N87-11966*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**THERMAL ANALYSIS OF RADIOMETER CONTAINERS FOR THE 122M HOOP COLUMN ANTENNA CONCEPT**
L. A. DILLON-TOWNES Sep. 1986 54 p
(NASA-TM-89026; NAS 1.15:89026) Avail: NTIS HC A04/MF A01 CSCL 20D

A thermal analysis was conducted for the 122 Meter Hoop Column Antenna (HCA) Radiometer electronic package containers. The HCA radiometer containers were modeled using the computer aided graphics program, ANVIL 4000, and thermally simulated using two thermal programs, TRASYS and MITAS. The results of the analysis provided relationships between the absorptance-emittance ratio and the average surface temperature of the orbiting radiometer containers. These relationships can be used to specify the surface properties, absorptance and reflectance, of the radiometer containers. This is an initial effort in determining the passive thermal protection needs for the 122 m HCA radiometer containers. Several recommendations are provided which expand this effort so specific passive and active thermal protection systems can be defined and designed. Author

**N87-14366*#** Harris Corp., Melbourne, Fla.
**DEVELOPMENT OF THE 15 METER DIAMETER HOOP COLUMN ANTENNA Final Report**
Washington NASA Dec. 1986 161 p
(Contract NAS1-15763)
(NASA-CR-4038; NAS 1.26:4038) Avail: NTIS HC A08/MF A01 CSCL 22B

The building of a deployable 15-meter engineering model of the 100 meter antenna based on the point-design of an earlier task of this contract, complete with an RF-capable surface is described. The 15 meter diameter was selected so that the model could be tested in existing manufacturing, near-field RF, thermal vacuum, and structural dynamics facilities. The antenna was designed with four offset paraboloidal reflector surfaces with a focal length of 366.85 in and a primary surface accuracy goal of .069 in rms. Surface adjustment capability was provided by manually resetting the length of 96 surface control cords which emanated from the lower column extremity. A detailed description of the 15-meter Hoop/Column Antenna, major subassemblies, and a history of its fabrication, assembly, deployment testing, and verification measurements are given. The deviation for one aperture surface (except the outboard extremity) was measured after adjustments in follow-on tests at the Martin Marietta Near-field Facility to be .061 in; thus the primary surface goal was achieved. Author

**N87-15377#** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
**L-BAND ANTENNAS FOR REGIONAL MOBILE COMMUNICATION SATELLITES**
A. ROEDERER *In* ESA Proceedings of an ESA Workshop on Land Mobile Services by Satellite p 75-80 Sep. 1986
Avail: NTIS HC A08/MF A01

Satellite L-band antennas ranging for state of the art small reflector systems to multibeam arrays, to large array-fed reflectors, with frequency reuse, flexible channel to beam allocation and/or steerable beam capabilities over an extended European coverage are reviewed. Both 2.5 to 5 m multifeed reflectors and foldable multibeam arrays are valid candidates for regional mobile communication satellites in the next decade. The foldable multibeam arrays have the major advantage over the multifeed reflectors of quasi-total traffic to beam allocation flexibility. In the longer term, when increase in traffic is such that on board minimum gains greater than 35 dBi are required, unfurlable reflectors with diameters greater than 10 m are preferable, since direct radiating arrays with equivalent aperture area cannot easily be deployed. Technologies for foldable arrays and reflectors up to 5 m diameter should be available for flight in the early nineties from present hardware developments. The same technology is applicable up to greater than 10 m, but with a serious additional effort required, particularly in testing. ESA

**N87-16019*#** Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
**ACTIVE CONTROL EVALUATION FOR SPACECRAFT (ACES)**
J. PEARSON and W. YUEN *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 67-84 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 22B

The Air Force goal is to develop vibration control techniques for large flexible spacecraft by addressing sensor, actuator, and control hardware and dynamic testing. The Active Control Evaluation for Spacecraft (ACES) program will address the Air Force goal by looking at two leading control techniques and implementing them on a structural model of a flexible spacecraft under laboratory testing. The first phase in the ACES program is to review and to assess the High Authority Control/Low Authority Control (HAC/LAC) and Filter accomodated Model Error Sensitivity Suppression (FAMESS) control techniques for testing on the modified VCOSS structure. Appropriate sensors and actuators will be available for use with both techniques; locations will be the same for both techniques. The control actuators will be positioned at the midpoint and free end of the structure. The laser source for the optical sensor is mounted on the feed mast. The beam will be reflected from a mirror on the offset antenna onto the detectors mounted above the shaker table bay. The next phase is to develop an analysis simulation with the control algorithms implemented for dynamics verification. The third phase is to convert the control laws into high level computer language and test them in the NASA-MSFC facility. The final phase is to compile all analytical and test results for performance comparisons. Author

**N87-16021*#** General Dynamics Corp., San Diego, Calif. Space Systems Div.
**DEPLOYABLE TRUSS STRUCTURE ADVANCED TECHNOLOGY**
J. E. DYER and M. P. DUDECK *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 111-124 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 22B

The 5-meter technology antenna program demonstrated the overall feasibility of integrating a mesh reflector surface with a deployable truss structure to achieve a precision surface contour compatible with future, high-performance antenna requirements. Specifically, the program demonstrated: the feasibility of fabricating a precision, edge-mounted, deployable, tetrahedral truss structure; the feasibility of adjusting a truss-supported mesh reflector contour to a surface error less than 10 mils rms; and good RF test

performance, which correlated well with analytical predictions. Further analysis and testing (including flight testing) programs are needed to fully verify all the technology issues, including structural dynamics, thermodynamics, control, and on-orbit RF performance, which are associated with large, deployable, truss antenna structures. Author

**N87-16022*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**DEVELOPMENT OF THE LENS ANTENNA DEPLOYMENT DEMONSTRATION (LADD) SHUTTLE-ATTACHED FLIGHT EXPERIMENT**
H. HILL, D. JOHNSTON, and H. FRAUENBERGER (Grumman Aerospace Corp., Bethpage, N.Y.) *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 125-144 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 20N

The primary objective of the LADD Program is to develop a technology demonstration test article that can be used for both ground and flight tests to demonstrate the structural and mechanical feasibility and reliability of the single-axis roll-out space based radar (SBR) approach. As designed, the LADD will essentially be a generic strucutural experiment which incorporates all critical technology elements of the operational satellite and is applicable to a number of future antenna systems. However, to fully determine its design integrity for meeting the lens flatness and constant geometry requirements in a zero g environment under extreme thermal conditions, the LADD must be space flight tested. By accurately surveying the structure under varying conditions the membrane tolerance-holding capabilities of the structure will be demonstrated. The flight test will provide data to verify analytical tools used to predict thermal and structural behavior. Most important, the experiment will provide an initial indication of structural damping in a zero g vacuum environment. The recently completed Solar Array Flight Experiment (SAFE) showed orbital damping greater than that experienced during ground testing. From the experience and the information obtained from LADD it is hoped that designs can be confidently extrapolated to operational satellites with apertures in the 20 m by 60 m size range. Author

**N87-16047*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**SURFACE CONTROL SYSTEM FOR THE 15 METER HOOP-COLUMN ANTENNA**
JAMES B. MILLER, ELVIN L. AHL, JR., DAVID H. BUTLER, and FRANK PERI, JR. *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 533-545 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 22B

The 15-meter hoop-column antenna fabricated by the Harris Corporation under contract to the NASA Langley Research Center is described. The antenna is a deployable and restowable structure consisting of a central telescoping column, a 15-meter-diameter folding hoop, and a mesh reflector surface. The hoop is supported and positioned by 48 quartz cords attached to the column above the hoop, and by 24 graphite cords from the base of the antenna column. The RF reflective surface is a gold plated molybdenum wire mesh supported on a graphite cord truss structure which is attached between the hoop and the column. The surface contour is controlled by 96 graphite cords from the antenna base to the rear of the truss assembly. The antenna is actually a quadaperture reflector with each quadrant of the surface mesh shaped to produce an offset parabolic reflector. Results of near-field and structural tests are given. Controls structures and electromagnetics interaction, surface control system requirements, mesh control adjustment, surface control system actuator assembly, surface control system electronics, the system interface unit, and control stations are discussed. Author

**N87-16871#** Integrated Systems, Inc., Palo Alto, Calif.
**ADAPTIVE CONTROL TECHNIQUES FOR LARGE SPACE STRUCTURES Annual Report, 1 Jun. 1985 - 31 May 1986**
ROBERT L. KOSUT and MICHAEL G. LYONS 15 Sep. 1986 117 p
(Contract F49620-85-C-0094)
(AD-A173083; ISI-85; AFOSR-86-0885TR) Avail: NTIS HC A06/MF A01 CSCL 22A

The Large Space Structure (LSS) research program was originally formulated in response to increasing concern that performance robustness of Air Force LSS systems would be inadequate to meet mission objectives. Uncertainties in both system dynamics and disturbance spectra characterizations (both time varying and stochastic uncertainty) significantly limit the performance attainable with fixed gain, fixed architecture controls. Therefore, use of an adaptive system, where disturbances and/or plant models are identified prior to or during control, gives systems designers more options for minimizing the risk in achieving performance objectives. The aim of adaptive control is to implement in real time and on line as many as possible of the design functions now performed off line by the control engineer to give the controller intelligence. To realize this aim, both a theory of stability and performance of such inherently nonlinear controls is essential as well as a technology capable of achieving the implementation. The present research concentrated on: (1) on line robust design from identified models - what is referred to here as adaptive calibration; and (2) an analysis of slow-adaptation for adaptive control for LSS. GRA

**N87-16880*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**COMPOSITE SPACE ANTENNA STRUCTURES: PROPERTIES AND ENVIRONMENTAL EFFECTS**
CAROL A. GINTY and NED M. ENDRES (Sverdrup Technology, Inc., Cleveland, Ohio) 1986 22 p Presented at the 18th International SAMPE Technical Conference, Seattle, Wash., 7-9 Oct. 1986
(NASA-TM-88859; E-3225; NAS 1.15:88859) Avail: NTIS HC A02/MF A01 CSCL 11D

The thermal behavior of composite spacecraft antenna reflectors has been investigated with the integrated Composites Analyzer (ICAN) computer code. Parametric studies have been conducted on the face sheets and honeycomb core which constitute the sandwich-type structures. Selected thermal and mechanical properties of the composite faces and sandwich structures are presented graphically as functions of varying fiber volume ratio, temperature, and moisture content. The coefficients of thermal expansion are discussed in detail since these are the critical design parameters. In addition, existing experimental data are presented and compared to the ICAN predictions. Author

**N87-16923#** European Space Agency, Paris (France).
**PROCEEDINGS OF THE SECOND ESA WORKSHOP ON MECHANICAL TECHNOLOGY FOR ANTENNAS**
E. J. ROLFE, ed. Noordwijk, Netherlands Aug. 1986 271 p Workshop held in Noordwijk, Netherlands, 20-22 May 1986
(ESA-SP-261; ISSN-0379-6566; ETN-87-98835) Avail: NTIS HC A12/MF A01

Deployable spacecraft antennas; antenna design; mechanical/electrical design verification; antenna components; and structure-attitude and orbit control system interactions were discussed.
ESA

**N87-16925#** Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany).
**EXPERIENCE GAINED BY SECTOR MODEL TESTING OF AN UNFURLABLE MESH/RIB ANTENNA**
H. HEINZE, H. HERBIG, and H. VORBRUGG *In* ESA Proceedings of the Second ESA Workhop on Mechanical Technology for Antennas p 17-22 Aug. 1986
(Contract ESTEC-5206/82-NL-PB(SC))
Avail: NTIS HC A12/MF A01

An unfurlable offset mesh antenna for communication satellite applications in the range 850 MHz to 12 GHz was designed. The reflector design concept should cover aperture diameters from 3.2 (12 GHz) to 12 m (850 MHz) with surface errors between 0.1 mm and 1.4 mm RMS. This versatility is met by a radial rib concept where foldable main ribs and intermediate ribs tension a gold plated molybdenum mesh to the required surface contour. The accuracy is varied by applying a different number of ribs (e.g., 16 for 850 MHz or 30 for 12 GHz) and mesh fastening points (so-called stand-offs). Tests with a two rib test model prove that the deployment and retraction system is reliable and that the mesh provides the required reflector surface. The configuration of the mesh is suitable in a range of frequencies up to 12 GHz. With the right mesh tension there are no passive intermodulation products. ESA

**N87-16926#** Societe Nationale Industrielle Aerospatiale, Les Mureaux (France). Space and Ballistics Systems.
**MECHANICAL AND CONTROL STUDY OF A 7 M OFFSET UNFURLABLE TRACKING ANTENNA**
G. LABRUYERE, L. PASSERON, M. PASTORINO, and E. SCHAFFAR *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 23-30 Aug. 1986
Avail: NTIS HC A12/MF A01

An antenna module for a tracking S-band satellite antenna mechanical concept is presented. The offset unfurlable reflector, the 15 deg antenna pointing mechanism, and the feed system support are described. Antenna pointing control, in presence of multiple flexible structures, is analyzed. ESA

**N87-16929#** Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
**ANALYSIS OF HIGH PRECISION COMPOSITE SANDWICH ANTENNAS**
G. HELWIG *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 51-55 Aug. 1986
Avail: NTIS HC A12/MF A01

A data base for all common types of spacecraft antenna skin and core materials was established. Based on these material properties, it is possible to predict accurately the performance of high precision antennas, and there is good agreement between analyses and tests. The orthotropic behavior of the sandwich should be improved by developments of skin and core materials. The research should be directed to a composite sandwich with an overall coefficient of expansion close to zero, giving composite sandwich panels with accuracies better than 1 micron rms for most kinds of temperature loads. ESA

**N87-16931#** Turin Univ. (Italy). Dipt. di Elettronica.
**DIELECTRIC SUPPORT STRUCTURES FOR SPACECRAFT ANTENNA FEEDS**
R. D. GRAGLIA, M. OREFICE, U. PONZI (Rome Univ., Italy), and S. SGUBINI *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 63-71 Aug. 1986
Avail: NTIS HC A12/MF A01

Analysis and design criteria for radio frequency transparent towers, to be used as support structures of feeds or subreflector in spacecraft reflector antennas are discussed. Candidate materials are fiber reinforced plastics, in particular those with good mechanical and dielectric properties, as aramid fiber (Kevlar). The electromagnetic analysis is performed by subdividing the structure in simple members (planes, cylinders, etc.) and considering each individual contribution to the scattering. Typical structures for offset and symmetrical configurations were considered, and design criteria are given. ESA

**N87-16933#** Nippon Telegraph and Telephone Public Corp., Yokosuka (Japan).
**DEVELOPMENT OF 30/20 GHZ SATELLITE ANTENNA STRUCTURES**
M. MINOMO and T. YASAKA *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 85-90 Aug. 1986
Avail: NTIS HC A12/MF A01

An antenna structural design for a large capacity communication satellite using 13 beams in the 30/20GHz frequency bands is discussed. This design is to be utilized in developing a more cost effective domestic satellite communication system for Japan. This system requires 2 high precision deployable antennas with projected aperture diameters of 3.5m at 20GHz and 2.5m at 30GHz. The in-orbit demonstration will use the ETS-6 satellite. Based on experience in the development of spaceborne antennas for 30/20GHz bands (e.g., for the CS-2 and CS-3 satellites) activities in structural design of high precision deployable antennas show the truss reflector structure is promising for achieving required structural properties. ESA

**N87-16934#** Spar Aerospace Ltd., Ste-Anne-de-Bellevue (Quebec).
**DESIGN OF A LOW DISTORTION SHARED APERTURE REFLECTOR**
L. DONATO and V. K. JHA *In* ESA Proceedings of the Second ESA Workhop on Mechanical Technology for Antennas p 91-96 Aug. 1986
(Contract CAN-DEPT-COMM-21ST-36100-3-031)
Avail: NTIS HC A12/MF A01

A design concept for a low thermal distortion dual gridded shared aperture reflector for satellite antennas is proposed. Low distortion characteristics result in improved on-orbit gain performance of the antenna system. The absence of an intercostal structure between reflectors improves electrical cross polar and gain performance. A finite difference model to predict temperatures of the reflector assembly was generated. From the temperature profiles a finite element model was used to evaluate the distortions of the parabolic surfaces. From the distorted best fit surfaces, pointing errors, defocussing, and rms deviation from the best fit parabola were evaluated and compared to thermal distortions of previous designs. The results show a significant improvement. ESA

**N87-16935#** Construcciones Aeronauticas S.A., Madrid (Spain). Space Div.
**CONSTRUCCIONES AERONAUTICAS S.A. (CASA) LARGE REFLECTOR ANTENNA**
J. ESCOBAR *In* ESA Proceedings of the Second ESA Workhop on Mechanical Technology for Antennas p 97-102 Aug. 1986
(Contract ESA-5277/82-NL-PP)
Avail: NTIS HC A12/MF A01

The development of a 11/14 GHz large reflector assembly is reviewed. Investigations on CFRP properties, their design and calculation methods, the development of the associated software, the gathering of a data base from tests at component level, and basic studies on the general configuration of antennas are outlined. A demonstration model to resolve the technological problems related with the design, manufacture and test of a large reflector was built. ESA

**N87-16936#** Selenia S.p.A., Rome (Italy).
**DEVELOPMENT OF LIGHTWEIGHT DIMENSIONALLY STABLE CARBON FIBER COMPOSITE ANTENNA REFLECTORS FOR THE INSAT-1 SATELLITE**
A. PACE, I. LAROSA, and R. STONIER *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 103-110 Aug. 1986
Avail: NTIS HC A12/MF A01

A lightweight dimensionally stable carbon fiber composite deployable antenna reflector structure utilizing a rib stiffened thin shell design was developed. Reflectors based on this design were manufactured and tested for the INSAT-1 satellites, and the same technology was used for the reflectors for the ARABSAT satellites. Structural materials were qualified and used on antenna reflector structures. The outstanding in-orbit performance of eight antennas on two INSAT-1 and two ARABSAT satellites, clearly demonstrates the technical success of the program. Three additional satellites with six more antennas/reflectors will be launched. ESA

**N87-16937#** Societe Nationale Industrielle Aerospatiale, Les Mureaux (France). Div. des Systems Balistiques et Spatiaux.
**STRUCTURAL ANALYSIS, MANUFACTURING AND DEVELOPMENT STATUS OF LARGE POLARIZATION SENSITIVE DUAL-GRIDDED REFLECTORS**
J. D. LEFEBVRE *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 111-121 Aug. 1986
Avail: NTIS HC A12/MF A01

The design of a 2.5 m diameter dual-gridded reflector assembly including the dynamic, static, thermal, and thermoelastic analyses is presented. The reflectors consist of two Kevlar sandwich shells, each being fitted with a grid of copper wires, and stiffened on the back by a system of Kevlar webs and struts. Mechanical and RF test results, performed on earlier developed reflector assemblies (1.4 m and 1.8 m) demonstrate the validity of the design. ESA

**N87-16941#** Construcciones Aeronauticas S.A., Madrid (Spain). Space and Systems Div.
**DEVELOPMENT OF MM-WAVE RADIOMETER ANTENNA REFLECTOR**
P. CORDERO, G. LOPEZ, and R. GARCIA *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 151-159 Aug. 1986
(Contract ESA-5263/82-NL-GM)
Avail: NTIS HC A12/MF A01

The development of an antenna for a passive microwave radiometer for the 90 to 300 GHz frequency range is discussed. The operating frequency-range imposes ultrahigh surface accuracy and stability, and electrical reflectivity close to that of the best conductive metals. Critical design areas and technological problems (e.g., CFRP metallizing) are reviewed. ESA

**N87-16942#** TICRA A/s, Copenhagen (Denmark).
**SIMPLE APPROACH FOR EVALUATING MECHANICAL REFLECTOR ANTENNA DISTORTIONS**
KNUD PONTOPPIDAN *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 165-170 Aug. 1986
Avail: NTIS HC A12/MF A01

Satellite reflector surface degradations originating from relatively slowly varying distortions, such as thermal deformations and creep are discussed. These surface errors scatter the field from the main beam into the region of the first few sidelobes, thereby deteriorating the isolation between frequency reuse beams. To investigate these errors, the concepts of Zernike modes are introduced. It is demonstrated how this method facilitates the insight and understanding of the physical phenomena occurring when a reflector surface is deformed. An inflatable antenna is used as a test example. ESA

**N87-16943#** Centro Studi e Laboratori Telecomunicazioni, Turin (Italy).
**PREDICTION OF THE ELECTRICAL PERFORMANCE OF INFLATABLE SPACE RIGIDIZED STRUCTURE (ISRS) OFFSET ANTENNA REFLECTORS AND CORRELATION WITH RF MEASUREMENTS**
E. PAGANA and M. C. BERNASCONI (Contraves Corp., Zurich, Switzerland) *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 171-177 Aug. 1986
Avail: NTIS HC A12/MF A01

The electrical design and testing at microwave frequencies (3 to 22 GHz) on the first Large Offset Antenna Demonstrator (LOAD) breadboard are summarized. The electrical analysis shows the quality of mock-up reflector and contributes to an electrical antenna model. The performance of a large inflatable antenna can be predicted, with good accuracy, only on the basis of the mechanical measurements of a proper set of reflector surface points. ESA

**N87-16944#** Contraves Italiana, Rome.
**CONTRAVES' ANTENNA TIP HINGE MECHANISM FOR SELENIA SPAZIO'S 20/30 GHZ ANTENNA**
D. STELLA, F. MORGANTI (Selenia S.p.A., Rome, Italy), and G. NIELSEN (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands) *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 185-194 Aug. 1986
Avail: NTIS HC A12/MF A01

A mechanism which can deploy a folded tip of an antenna in orbit, the Antenna Tip Hinge Mechanism (ATHM) was developed. The ATHM consists of two hinges, each near the edge of the antenna main body and tip interface. Following a command, the antenna tip is released and spiral springs drive the antenna tip to its end position, where latches secure the tip in place. No damping or any form of energy dissipation is provided for, other than that which is caused by friction within the system. Two ATHM's, one at each end of the antenna, enable a 20/30 GHz multibeam antenna to fit in the Ariane 4 shroud. This mechanism can, with minor modifications, be used to deploy a multitude of different systems, provided that they are not too fragile to withstand the deceleration loads that occur at the end of deployment. ESA

**N87-17824*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**MATHEMATICAL MODELING OF SCOLE CONFIGURATION WITH LINE-OF-SIGHT ERROR AS THE OUTPUT**
S. M. JOSHI *In its* Proceedings of the 3rd Annual SCOLE Workshop p 83-92 Jan. 1987
Avail: NTIS HC A20/MF A01 CSCL 22B

The Spacecraft Control Laboratory Experiment (SCOLE) linear model; Taylor's coordinate system; Robertson's system; and the flexible linear model are presented. B.G.

**N87-17826*#** Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.
**MODELING AND IDENTIFICATION OF SCOLE**
L. MEIROVITCH and M. A. NORRIS *In* NASA. Langley Research Center Proceedings of the 3rd Annual SCOLE Workshop p 109-120 Jan. 1987
Avail: NTIS HC A20/MF A01 CSCL 22B

Vector differential equations for distributed structures; discretization (in space) of distributed structures; and parameter identification for the Spacecraft Control Laboratory Experiment (SCOLE) are examined. B.G.

**N87-17828*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**FINITE ELEMENT MODEL OF SCOLE LABORATORY CONFIGURATION**
BETH LEE, JEFFREY P. WILLIAMS, and DEAN SPARKS *In its* Proceedings of the 3rd Annual SCOLE Workshop p 149-162 Jan. 1987
Avail: NTIS HC A20/MF A01 CSCL 22B

The Spacecraft Control Laboratory Experiment (SCOLE) is defined by element properties: material constants; mast, reflector, rigid links as beam elements; cable as bar element; and space shuttle as very stiff beam. Two boundary conditions are modeled: suspended (6 degrees of freedom for all joints except the top of the cable) and cantilevered cables (shuttle platform fixed in all degrees of freedon). Calculations include stiffness and mass matrices, initial stresses, static displacements and reactions, and eigensolutions. B.G.

**N87-17829*#** Rensselaer Polytechnic Inst., Troy, N.Y. Dept. of Electrical, Computer and Systems Engineering.
**MODEL REFERENCE CONTROL OF DISTRIBUTED PARAMETER SYSTEMS: APPLICATION TO THE SCOLE PROBLEM**
H. KAUFMAN, D. MINNICK, M. BALAS, and A. MUSALEM *In* NASA. Langley Research Center Proceedings of the 3rd Annual SCOLE Workshop p 163-228 Jan. 1987
Avail: NTIS HC A20/MF A01 CSCL 22B

The model reference control of lumped linear systems and the model reference control of the distributed parameter system (DPS) are presented with their theory and Spacecraft Control Laboratory Experiment (SCOLE) applications. B.G.

**N87-17830*#** Naval Research Lab., Washington, D.C.
**PROOF-MASS ACTUATOR PLACEMENT STRATEGIES FOR REGULATION OF FLEXURE DURING THE SCOLE SLEW**
SHALOM (MIKE) FISHER *In* NASA. Langley Research Center Proceedings of the 3rd Annual SCOLE Workshop p 229-260 Jan. 1987
Avail: NTIS HC A20/MF A01 CSCL 22B

An analysis was performed in order to find the best placement for proof-mass actuators and to determine the importance of placement, i.e., what is the sensitivity of beam flexure to actuator placement. The analysis was performed by using the NASTRAN finite element model for a flexible beam with 21 grid points on beam, by using the nonlinear DISCOS simulation of 20 deg slew and the use of a closed-loop linear quadratic regulator (lqr). Some conclusions reached are: (1) proof-mass actuators can reduce flexure amplitude and damp oscillations; (2) amplitude of deformations during slew is relatively insensitive to placement of actuators; (3) damping factor of oscillations is sensitive to actuator placement; and (4) the degree of controllability method indicates most effective placement for actuators. E.R.

**N87-17831*#** Control Research Corp., Lexington, Mass.
**ACTIVE DAMPING OF VIBRATIONS IN SCOLE EXCITED BY SLEWING**
JIGUAN GENE LIN *In* NASA. Langley Research Center Proceedings of the 3rd Annual SCOLE Workshop p 261-312 Jan. 1987
Avail: NTIS HC A20/MF A01 CSCL 22B

Control simulations were performed to study active damping of vibrations in SCOLE excited by minimum-time rapid slewing. Highlights of the numerical results are presented. Some conclusions reached are: (1) modal-dashpot and modal-spring controllers provide quick and effective vibration control; (2) high gain problems can be avoided by proper selection of modeled modes and proper level of augmentation; (3) modal dashpots and modal springs are most effective during the initial period of large vibrations; and (4) line of sight error due solely to each mode excited by the disturbance provides a sound measure of importance of individual modes. E.R.

**N87-17832*#** Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.
**CONTROL OF SCOLE**
L. MEIROVITCH and M. A. NORRIS *In* NASA. Langley Research Center Proceedings of the 3rd Annual SCOLE Workshop p 313-320 Jan. 1987
Avail: NTIS HC A20/MF A01 CSCL 22B

A relatively low order model is used to control SCOLE. Drastic truncation of the discretized model is proposed by means of a modal expansion. An open loop eigenvalue problem is illustrated as is truncated modal equations, modal state equations, actual output vector and modal Kalman filter. Also illustrated is independent modal-space control. E.R.

**N87-17833*#** Purdue Univ., West Lafayette, Ind.
**REGULATION OF THE SCOLE CONFIGURATION**
GREGORY A. NORRIS, EMMANUEL G. COLLINS, and ROBERT E. SKELTON *In* NASA. Langley Research Center Proceedings of the 3rd Annual SCOLE Workshop p 321-336 Jan. 1987
Avail: NTIS HC A20/MF A01 CSCL 22B

Studies were performed to determine location for proof mass actuators, if a significant reduction in the number of sensors would work, and to design a control law to meet requirements for line of sight error and actuators. Conclusions are drawn and briefly discussed. E.R.

**N87-18598*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**INTEGRATED STRUCTURE ELECTROMAGNETIC OPTIMIZATION OF LARGE SPACE ANTENNA REFLECTORS**
SHARON L. PADULA, HOWARD M. ADELMAN, and M. C. BAILEY Feb. 1987 12 p Proposed for presentation at the AIAA/ASME/ASCE/AHS 28th Structures, Structural Dynamics and Materials Conference, Monterey, Calif., 6-8 Apr. 1987
(NASA-TM-89110; NAS 1.15:89110; AIAA-87-0824-CP) Avail: NTIS HC A02/MF A01 CSCL 22B

The requirements for extremely precise and powerful large space antenna reflectors have motivated the development of a procedure for shape control of the reflector surface. A mathematical optimization procedure has been developed which improves antenna performance while minimizing necessary shape correction effort. In contrast to previous work which proposed controlling the rms distortion error of the surface thereby indirectly improving antenna performance, the current work includes electromagnetic (EM) performance calculations as an integral of the control procedure. The application of the procedure to a radiometer design with a tetrahedral truss backup structure demonstrates the potential for significant improvement. The results indicate the benefit of including EM performance calculations in procedures for shape control of large space antenna reflectors. Author

# 09

# PROPULSION

Includes descriptions of analytical techniques, analyses, systems, and requirements for internal and external communications, electronics, sensors for position and systems monitoring and antennas.

**A87-12092**

**A FUNDAMENTAL STUDY OF THE ALKALINE-MATRIX-TYPE FUEL CELL SYSTEM FOR SPACE VEHICLES**

K. KIKUCHI, T. OZEKI, Y. YOSHIDA (Mitsubishi Heavy Industries Ltd., Nagoya Aircraft Works, Japan), Y. FUJITA, and H. NAKAMURA (Japan Storage Battery Co., Kyoto, Japan) (University of Tokyo, Institute of Space and Astronautical Science, Space Energy Symposium, 4th, Tokyo, Japan, Mar. 1, 1985) Space Solar Power Review (ISSN 0191-9067), vol. 5, no. 4, 1985, p. 371-384.

An alkaline-matrix-type fuel cell system consisting of an improved five cell stack, a reactant supply system, and a control unit was developed for a test bed, with application to vehicles such as the Space Station and the orbital transfer vehicle. Tests were performed with gaseous hydrogen and Fluorinert FC-40 circulated to control the dew point of gaseous hydrogen and the operating temperature, and product water from the cell stack, carried away with circulating gaseous hydrogen, was removed from the hydrogen steam by condensation. The system demonstrated a power of 90 W at a standard load current of 20 A, and a power of 147.7 W at a maximum load current of 35 A under an operating pressure of 0.4 MPa. For sudden change in the load current, the terminal voltage reacted quickly and the reactant supply system and the control unit operated satisfactorily. The terminal voltage was stable in the temperature range tested, though the terminal voltage dropped at a temperature of the cell stack of 78 C and of the condenser of 72 C. R.R.

**A87-15873#**

**ADVANCED SPACE PROPULSION CONCEPTS**

D. GEORGE (USAF, Rocket Propulsion Laboratory, Edwards AFB, CA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 13 p. refs

(IAF PAPER 86-110)

The Air Force Rocket Propulsion Laboratory is developing space propulsion having various attributes to meet the transport challenges imposed by modern spacecraft. Cryogenic (oxygen/hydrogen) propellant concepts that are being developed include a low thrust engine and compact cryogenic feed system. These provide substantial benefit to orbit transfer vehicles since they maximize both volume and weight to the payload carrying capability of the stage from LEO to GEO. A modular storable space propulsion concept provides flexibility to size stages in a building block manner to satisfy payload requirements. Further, individual stage and integral propulsion options are made available. Nonchemical propulsion concept technologies include arcjet and solar thermal propulsion systems which can provide increased payload delivery to various orbits. Author

**A87-15921#**

**PROPULSION FOR THE SPACE STATION**

V. R. LARSON and S. A. EVANS (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 17 p. refs

(IAF PAPER 86-182)

The principal requirements for an on-board propulsion system for the Space Station are briefly reviewed, and a baseline propulsion system based on hydrogen/oxygen thrusters using an on-board water electrolysis system to provide the propellants is described. This system is combined with a low thrust (100 millipounds) resistojet propulsion module that can operate using excess or waste fluids. This combined on-board propulsion system eliminates the need to transport propellants to orbit as well as the need to collect, store, and return waste fluids to earth. The design of the propulsion thrusters is examined, with attention given to maintenance and servicing aspects. V.L.

**A87-15922#**

**A NEW GENERATION OF SPACE ENGINES**

A. SIEBENHAAR (Aerojet TechSystems Co., Sacramento, CA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 10 p.

(IAF PAPER 86-184)

A primary method of launching future spacecraft will be the STS. Studies have identified minimum-length stages capable of lifting heavy and deployed payloads from the STS LEO to GEO using storable or cryogenic propulsion systems. The development of two engines suitable for these stages, a storable engine in the few thousand pound thrust range, and a cryogenic engine with a thrust of only a few hundred pounds, is reported. The storable-engine breadboard testing has been accomplished, and the flight-weight development program will be complete by the end of this decade. The low-thrust cryogenic engine lags this storable engine by approximately three years in development and availability. Author

**A87-21515#**

**COMMONALITY INFLUENCES ON SPACE STATION PROGRAM PROPULSION SYSTEM SELECTION**

LARRY ROSE (Martin Marietta Corp., Denver, CO) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 22nd, Huntsville, AL, June 16-18, 1986. 5 p.

(AIAA PAPER 86-1563)

One of the major evaluations involved in the Space Station program is the selection of the propellants to be used for the Space Station elements. This involves selecting the propellants to be used not only on board the Space Station but on the free flyer platforms and the OMV. One of the primary goals of the Space Station program is to maximize commonality between elements of the program to reduce total program costs. A study was made to determine the degree of commonality that is possible for the propulsion systems. This study also examined what level of commonality would produce the most economic benefit to the program. The results of the study showed that the most effective use of commonality was not, as was first thought, the use of a single propellant combination for all the propulsion elements. The similarities of OMV and platform requirements drive these two to use the same propellant system. However, because of the Space Station's unique requirements and capabilities, it is not sensitive to the other elements commonality. Instead, the Space Station's sensitivity to its own requirements makes it most economical to have its own specific propulsion system design. The disadvantage of additional development costs is outweighed by the reduced cost of delivering propellant to the Space Station. Author

**A87-24997*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**HIGH- AND LOW-THRUST PROPULSION SYSTEMS FOR THE SPACE STATION**

ROBERT E. JONES (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 13 p. Previously announced in STAR as N87-14427. refs

(AIAA PAPER 87-0398)

The purpose of the Advanced Development program was to investigate propulsion options for the space station. Two options were investigated in detail: a high-thrust system consisting of 25 to 50 lbf gaseous oxygen/hydrogen rockets, and a lwo-thrust system of 0.1 lbf multipropellant resistojets. An effort is also being conducted to determine the life capability of hydrazine-fueled thrusters. During the course of this program, studies clearly identified the benefits of utilizing waste water and other fluids as propellant sources. The results of the H/O thruster test programs are presented and the plan to determine the life of hydrazine thrusters is discussed. The background required to establish a

long-life resistojet is presented and the first design model is shown in detail. Author

**A87-24998*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**AN ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF RESISTOJET PLUMES**

LYNNETTE M. ZANA, DAVID J. HOFFMAN (NASA, Lewis Research Center, Cleveland, OH), LORANELL R. BREYLEY, and JOHN S. SERAFINI (Akron, University, OH) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 13 p. Previously announced in STAR as N87-14428. refs

(AIAA PAPER 87-0399)

As a part of the electrothermal propulsion plume research program at the NASA Lewis Research Center, efforts have been initiated to analytically and experimentally investigate the plumes of resistojet thrusters. The method of Simons for the prediction of rocket exhaust plumes is developed for the resistojet. Modifications are made to the source flow equations to account for the increased effects of the relatively large nozzle boundary layer. Additionally, preliminary mass flux measurements of a laboratory resistojet using CO2 propellant at 298 K have been obtained with a cryogenically cooled quartz crystal microbalance (QCM). There is qualitative agreement between analysis and experiment, at least in terms of the overall number density shape functions in the forward flux region. Author

**A87-28951**

**ADVANCED PROPULSION SYSTEMS FOR SPACE STATION APPLICATIONS**

D. G. FEARN and N. C. WALLACE (Royal Aircraft Establishment, Space Dept., Farnborough, England) British Interplanetary Society, Journal (Space Stations) (ISSN 0007-084X), vol. 40, Jan. 1987, p. 3-10. refs

From a consideration of the propulsion requirements of the various elements of the Space Station, it is concluded that propellant consumption will be a major cost factor, especially for functions requiring large total impulses. Electric propulsion (EP) systems offer exhaust velocities at least an order of magnitude higher than those of chemical thrusters reducing propellant masses by the same factor. Consequently, it is recommended that EP systems be employed for high-impulse tasks such as drag compensation and orbit transfer. It is shown that the propellant mass required for drag compensation on the main Space Station can be reduced from several tonnes annually to a few hundred kg, and that the Polar Platform's initial orbit-transfer maneuver can be accomplished for well under 100 kg, rather than the 500-1000 kg needed by a bipropellant system. The limitations imposed by the power demands of the proposed EP systems are also considered; they can be significantly restrictive in some cases. Author

**N87-14427*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**HIGH- AND LOW-THRUST PROPULSION SYSTEMS FOR THE SPACE STATION**

R. E. JONES 1987 23 p Presented at the 25th Aerospace Sciences Meeting, Reno, Nev., 12-15 Jan. 1987; sponsored by AIAA

(NASA-TM-88877; E-3285; NAS 1.15:88877) Avail: NTIS HC A02/MF A01 CSCL 21H

The purpose of the Advanced Development program was to investigate propulsion options for the space station. Two options were investigated in detail: a high-thrust system consisting of 25 to 50 lbf gaseous oxygen/hydrogen rockets, and a low-thrust system of 0.1 lbf multipropellant resistojets. An effort is also being conducted to determine the life capability of hydrazine-fueled thrusters. During the course of this program, studies clearly identified the benefits of utilizing waste water and other fluids as propellant sources. The results of the H/O thruster test programs are presented and the plan to determine the life of hydrazine thrusters is discussed. The background required to establish a long-life resistojet is presented and the first design model is shown in detail. Author

**N87-14428*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**AN ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF RESISTOJET PLUMES**

L. M. ZANA, D. J. HOFFMAN, L. R. BREYLEY (Akron Univ., Ohio), and J. S. SERAFINI Jan. 1987 22 p Presented at the 25th Aerospace Sciences Meeting, Reno, Nev., 12-15 Jan. 1987; sponsored by AIAA

(NASA-TM-88852; E-3243; NAS 1.15:88852) Avail: NTIS HC A02/MF A01 CSCL 21H

As a part of the electrothermal propulsion plume research program at the NASA Lewis Research Center, efforts have been initiated to analytically and experimentally investigate the plumes of resistojet thrusters. The method of G.A. Simons for the prediction of rocket exhaust plumes is developed for the resistojet. Modifications are made to the source flow equations to account for the increased effects of the relatively large nozzle boundary layer. Additionally, preliminary mass flux measurements of a laboratory resistojet using CO2 propellant at 298 K have been obtained with a cryogenically cooled quartz crystal microbalance (QCM). There is qualitative agreement between analysis and experiment, at least in terms of the overall number density shape functions in the forward flux region. Author

**N87-16065*#** Sverdrup Technology, Inc., Cleveland, Ohio.

**POTENTIAL PROPELLANT STORAGE AND FEED SYSTEMS FOR SPACE STATION RESISTOJET PROPULSION OPTIONS Final Report**

CLAYTON H. BADER Jan. 1987 63 p

(Contract NAS3-24105)

(NASA-CR-179457; E-3366; NAS 1.26:179457) Avail: NTIS HC A04/MF A01 CSCL 21H

The resistojet system has been defined as part of the baseline propulsion system for the initial Operating Capability Space Station. The resistojet propulsion module will perform a reboost function using a wide variety of fluids as propellants. There are many optional propellants and propellant combinations for use in the resistojet including (but not limited to): hydrazine, hydrogen, oxygen, nitrogen, water, carbon dioxide, and methane. Many different types of propulsion systems have flown or have been conceptualized that may have application for use with resistojets. This paper describes and compares representative examples of these systems that may provide a basis for space station resistojet system design. Author

**N87-16066#** Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.

**AN ECONOMIC FEASIBILITY STUDY ON THE SPACE-BASED PRODUCTION OF METHANE GAS FROM HUMAN WASTE THROUGH ANAEROBIC DIGESTION FOR USE AS AN ORBIT MAINTENANCE PROPELLANT M.S. Thesis**

CORAL C. FALLSTEAD Dec. 1985 149 p

(AD-A172496; AFIT/GSO/ENS/85D-8) Avail: NTIS HC A07/MF A01 CSCL 22B

This project explores the economic feasibility of creating fuel energy in space from human waste with application toward space station orbit maintenance. The energy generating concept proposed in this study is anaerobic digestion. This process has four benefits for space application: (1) it can stabilize human waste products, (2) it can reduce solid wastes, (3) it can provide a fairly clear effluent for water recovery, and (4) it can provide a fuel in the form of a gas. The analysis is dependent upon a predetermined scenario defining the input load to the digester system and the size of the spacecraft. The size, shape, and altitude of the vehicle determine the atmospheric drag which must be opposed to maintain the orbit. The basic elements of the study involve: (1) simulation analysis of biochemistry, (2) thermochemical analysis, and (3) cost analysis using the Monte Carlo method. An alternative system to which the digester is compared is transport of conventional propellants from Earth. This alternative does not consider a

replacement of the anaerobic digester with some other system to stabilize the waste products of the space station, or the additional benefits of the anaerobic digester listed above. The results of this study show a statistically significant advantage of the digester system over transported conventional propellants due to the high cost of space transportation. GRA

**N87-16874*#** Textron Bell Aerospace Co., Buffalo, N. Y.
**SPACE STATION AUXILIARY THRUST CHAMBER TECHNOLOGY Final Report**
J. M. SENNEFF Aug. 1986 196 p
(Contract NAS3-24656)
(NASA-CR-179552; NAS 1.26:179552; REPT-8911-950001)
Avail: NTIS HC A09/MF A01 CSCL 21H

A program to design, fabricate and test a 50 lb sub f (222 N) thruster was undertaken (Contract NAS 3-24656) to demonstrate the applicability of the reverse flow concept as an item of auxiliary propulsion for the space station. The thruster was to operate at a mixture ratio (O/F) of 4, be capable of operating for 2 million lb sub f- seconds (8.896 million N-seconds) impulse with a chamber pressure of 75 psia (52 N/square cm) and a nozzle area ratio of 40. Superimposed was also the objective of operating with a strainless steel spherical combustion chamber, which limited the wall temperature to 1700 F (1200 K), an objective specific impulse of 400 lb sub f sec/lbm (3923 N-seconds/Kg), and a demonstration of 500,000 lb sub f-seconds (2,224,000 N-seconds) of impulse. The demonstration of these objectives required a number of design iterations which eventually culminated in a very successful 1000 second demonstration, almost immediately followed by a changed program objective imposed to redesign and demonstrate at a mixture ratio (O/F) of 8. This change was made and more then 250,000 lb sub f seconds (1,112,000 N-seconds) of impulse was successfully demonstrated at a mixture ratio of 8. This document contains a description of the effort conducted during the program to design and demonstrate the thrusters involved. Author

**N87-20477*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**RESISTOJET CONTROL AND POWER FOR HIGH FREQUENCY AC BUSES**
ROBERT P. GRUBER 1987 33 p Presented at the 19th International Electric Propulsion Conference, Colorado Springs, Colo., 11-13 May 1987; sponsored by AIAA, DGLR and JSASS
(NASA-TM-89860; E-3527; NAS 1.15:89860; AIAA-87-0994)
Avail: NTIS HC A03/MF A01 CSCL 09C

Resistojets are operational on many geosynchronous communication satellites which all use dc power buses. Multipropellant resistojets were selected for the Initial Operating Capability (IOC) Space Station which will supply 208 V, 20 kHz power. This paper discusses resistojet heater temperature controllers and passive power regulation methods for ac power systems. A simple passive power regulation method suitable for use with regulated sinusoidal or square wave power was designed and tested using the Space Station multipropellant resistojet. The breadboard delivered 20 kHz power to the resistojet heater. Cold start surge current limiting, a power efficiency of 95 percent, and power regulation of better than 2 percent were demonstrated with a two component, 500 W breadboard power controller having a mass of 0.6 kg. Author

# 10

# MECHANISMS, AUTOMATION, AND ARTIFICIAL INTELLIGENCE

Includes descriptions of simulations, models, analytical techniques, and requirements for remote, automated and robotic mechanical systems.

**A87-12219#**
**AEROSPACE APPLICATIONS OF AI**
W. S. FAUGHT (Intellicorp, Mountain View, CA) IN: Annual Aerospace Applications of Artificial Intelligence Conference, 1st, Dayton, OH, September 16-19, 1985, Proceedings . Dayton, OH, AAAIC Secretariat, 1985, p. 331-344.

Human expertise has traditionally been expensive, nonrealtime, and in short supply. AI appears to offer an opportunity to: capture and retain expertise built up over many years and system and organization operation; amplify expertise needed to deploy new aerospace technologies and design applications; and offer systems which reason intelligently about necessary actions to take in real-time, thus freeing human operations personnel. The goal of commercial AI tool development is to identify AI techniques to enhance the tools and support the development of tools enhancements that are focused on aerospace applications. Several such applications are described, including fault diagnosis, simulation, scheduling, tracking and monitoring, configuration selection and testing. Author

**A87-13301**
**1986 AMERICAN CONTROL CONFERENCE, 5TH, SEATTLE, WA, JUNE 18-20, 1986, PROCEEDINGS. VOLUMES 1, 2, & 3**
Conference sponsored by the American Automatic Control Council. New York, Institute of Electrical and Electronics Engineers, 1986. Vol. 1, 678 p.; vol. 2, 757 p.; vol. 3, 807 p. For individual items see A87-13302 to A87-13460.

Papers are presented on robustness and modeling issued in process control, stochastic control, stability theory for adaptive control, robotics, artificial intelligence in process control, direct-drive robot arms, and estimation and tracking. Also considered are performance/robustness tradeoffs inc ontroller design, linear and nonlinear systems, advances in model predictive control, simulation tools for control systems, control of flexible spacecraft, missile navigation, guidance and control, and aerospace and aircraft control applications. Other topics include real-time applications of parallel processing technology, identification, control in mechanical and optical systems, web handling, and reconfiguration strategies for flight control systems. R.R.

**A87-13494*** Colorado State Univ., Fort Collins.
**NONLINEAR INTERFACES FOR ACCELERATION-COMMANDED CONTROL OF SPACECRAFT AND MANIPULATORS**
T. A. W. DWYER, III, G. K. F. LEE, and N. CHEN (Colorado State University, Fort Collins) IN: Applied numerical modeling . San Diego, CA, Univelt, Inc., 1986, p. 517-522. refs
(Contract NSF ECS-83-04968; NAG1-436; F49620-83-K-0032)

Nominal command generation in real time for the control of manipulators or of maneuvering spacecraft is hampered by the nonlinearity of the equations of motion. Likewise the real time tracking of a computed nominal trajectory in the presence of disturbances requires the computation of time-varying Jacobians of the motion. An alternative approach is the formulation of acceleration-commanded control laws in appropriately chosen generalized advantageous to design dedicated circuit interfaces to perform the required transformation. It is also possible to guarantee that actuator and sensor saturation limits are not exceeded, by means of feedback-biased circuits that implement automatic overload limitation of acceleration commands. Recent developments following this 'hardware computation' point of view will be discussed. Author

**A87-13705**
**SPACE STATION AUTOMATION; PROCEEDINGS OF THE MEETING, CAMBRIDGE, MA, SEPTEMBER 17, 18, 1985**
W. C. CHIOU, SR., ED. (Lockheed Research Laboratories, Palo Alto, CA) Meeting sponsored by SPIE. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Volume 580), 1985, 105 p. For individual items see A87-13706 to A87-13717.
(SPIE-580)

Applications of artificial intelligence (AI), image science and robotics to enhancing automation for implementation in Space Station (SS) operations are discussed and current research is reviewed. Attention is given to the functional requirements, missions and potential configurations of automation and robotics on space stations, orbital maneuvering vehicles and the Orbiter. Expert systems are investigated for control of power transmission and consumption in the SS Common Modules. Automated guidance, position and target location sensors and image processors and docking systems for orbital maneuver systems are described. Consideration is devoted to robot vision techniques for welding, collision avoidance, automated life sciences experimentation, and automated SS inspection systems. Finally, a systems approach is delineated for use in the design of the SS and the selection of its missions. M.S.K.

**A87-13706*** National Aeronautics and Space Administration, Washington, D.C.
**THE ROLE OF AUTOMATION AND ROBOTICS IN SPACE STATIONS**
D. C. BLACK (NASA, Office of Space Station, Washington, DC) IN: Space station automation; Proceedings of the Meeting, Cambridge, MA, September 17, 18, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1985, p. 2-9.

Automation and robotics have played important roles in space research, most notably in planetary exploration. While an increased need for automation and robotics in space research is anticipated, some of the major challenges and opportunities for automation and robotics will be provided by the Space Station. Examples of these challenges are briefly reviewed. Author

**A87-13707*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**SPACE MISSIONS FOR AUTOMATION AND ROBOTICS TECHNOLOGIES (SMART) PROGRAM**
D. L. CIFFONE and H. LUM, JR. (NASA, Ames Research Center, Moffett Field, CA) IN: Space station automation; Proceedings of the Meeting, Cambridge, MA, September 17, 18, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1985, p. 10-16.

The motivations, features and expected benefits and applications of the NASA SMART program are summarized. SMART is intended to push the state of the art in automation and robotics, a goal that Public Law 98-371 mandated be an inherent part of the Space Station program. The effort would first require tests of sensors, manipulators, computers and other subsystems as seeds for the evolution of flight-qualified subsystems. Consideration is currently being given to robotics systems as add-ons to the RMS, MMU and OMV and a self-contained automation and robotics module which would be tended by astronaut visits. Probable experimentation and development paths that would be pursued with the equipment are discussed, along with the management structure and procedures for the program. The first hardware flight is projected for 1989. M.S.K.

**A87-13708**
**THE SYSTEM APPROACH FOR APPLYING ARTIFICIAL INTELLIGENCE TO SPACE STATION AUTOMATION**
V. L. GROSE (National Transportation Safety Board, Washington, DC) IN: Space station automation; Proceedings of the Meeting, Cambridge, MA, September 17, 18, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1985, p. 21-27.

The systems approach and an establishment issue Totem Pole (EITP) are described as a means to facilitate the incorporation of artificial intelligence features into the Space Station (SS). It is recommended that, in order to take a systems approach, the geography of the SS be defined explicitly, along with the known inputs and desired outputs and a balance between cost, performance and schedule. The evolutionary, dynamic character of the SS must be acknowledged to recognize that the outputs will change the objectives. The EITP is to be developed from a functional flow block diagram, which is a product of intended inputs and desired outputs. The means used to achieve an SS which could use the inputs and produce the outputs are ranked in terms of criticality. AI then incorporates the hierarchy and will allocate resources in a sequence that will yield the best return on minimal resource investment. M.S.K.

**A87-13712**
**AN INTRODUCTION TO THE CONCEPT OF ROBOT FACTORS AND ITS APPLICATION TO SPACE STATION AUTOMATION**
W. C. CHIOU, SR. (Lockheed Research Laboratories, Palo Alto, CA) and S. A. STARKS (Texas, University, Arlington) IN: Space station automation; Proceedings of the Meeting, Cambridge, MA, September 17, 18, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1985, p. 53-57.

Basic operating considerations resulting from the unique environment of space are discussed, along with those resulting from the current and projected state of Automation and Robotics (A&R) which will influence the initial layout and maintenance of the Space Station. A concept called 'robot-factors' is introduced which deals with the telerobot working environment and its organizational relationships with other robots. The robot factors are considered from the point of view of the overall system architecture of the Space Station. Design considerations concerning the physical nature of the Space Station complex, as well as those concerning the data management system, are examined. Emphasis is on making the robot's tasks safe and easy to perform, and on the telerobot's welfare in terms of that of other cooperating telerobots in the performance of a common task. Author

**A87-13713**
**SPACE STATION AUTOMATION - THE ROLE OF ROBOTICS AND ARTIFICIAL INTELLIGENCE**
W. T. PARK and O. FIRSCHEIN (SRI International, Menlo Park, CA) IN: Space station automation; Proceedings of the Meeting, Cambridge, MA, September 17, 18, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1985, p. 60-67.

Automation of the Space Station is necessary to make more effective use of the crew, to carry out repairs that are impractical or dangerous, and to monitor and control the many Space Station subsystems. Intelligent robotics and expert systems play a strong role in automation, and both disciplines are highly dependent on a common artificial intelligence (AI) technology base. The AI technology base provides the reasoning and planning capabilities needed in robotic tasks, such as perception of the environment and planning a path to a goal, and in expert systems tasks, such as control of subsystems and maintenance of equipment. Automation concepts for the Space Station are described, along with the specific robotic and expert systems and the R&D required to attain this automation. An evolutionary development plan is presented that leads to fully automatic mobile robots for servicing satellites. The sequence of demonstrations and the R&D needed to confirm the automation capabilities are summarized. It is emphasized that advanced robotics requires AI, and that to advance, AI needs the 'real-world' problems provided by robotics. Author

**A87-13714*** Massachusetts Inst. of Tech., Cambridge.
**REMOTELY MANIPULATED AND AUTONOMOUS ROBOTIC WELDING FABRICATION IN SPACE**
J. E. AGAPAKIS (Automatix, Inc., Billerica, MA) and K. MASUBUCHI (MIT, Cambridge, MA) IN: Space station automation; Proceedings of the Meeting, Cambridge, MA, September 17, 18, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1985, p. 68-77. NASA-MIT-supported research. refs

The results of a NASA sponsored study, performed in order to establish the feasibility of remotely manipulated or unmanned welding fabrication systems for space construction, are presented. Possible space welding fabrication tasks and operational modes are classified and the capabilities and limitations of human operators and machines are outlined. Human performance in remote welding tasks was experimentally tested under the sensing and actuation constraints imposed by remote manipulation in outer space environments. Proposals for the development of space welding technology are made and necessary future R&D efforts are identified. The development of improved visual sensing strategies and computer encoding of the human welding engineering expertise are identified as essential, both for human operator assistance and for autonomous operation in all phases of welding fabrication. Novel uses of machine vision for the determination of the weld joint and bead geometry are proposed, and a prototype of a rule-based expert system is described for the interpretation of the visually detected weld features and defects. Author

**A87-13715**
**MULTIARM COLLISION AVOIDANCE USING THE POTENTIAL-FIELD APPROACH**
J. K. MYERS (SRI International, Menlo Park, CA) IN: Space station automation; Proceedings of the Meeting, Cambridge, MA, September 17, 18, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1985, p. 78-87. refs
(Contract F49620-82-K-0034)

A generalized potential-field approach to manipulator collision avoidance is presented. The potential-field approach consists of four algorithms: repulsion away from obstacles, attraction towards a goal, a method of combining these, and a resulting method of incrementing the arm. Alternatives for these algorithms are discussed. A multiple-robot system demonstrating the concepts is described. The system uses a detailed rigid model of the entire arms and surrounding objects to avoid collisions. The system operates in close-to-real-time, and is demonstrated with two PUMA robots moving concurrently. Results are applicable to any type of anthropomorphic arm, including the Remote Manimulator System. Author

**A87-13949**
**MATTER OF EASE**
W. H. GREGORY Commercial Space (ISSN 8756-4831), vol. 2, Summer 1986, p. 58-60.

The following human factors and robotics research vehicles, developed at the Massachusetts Institute of Technology, are presented: (1) Beam Assembly Teleoperator, (2) Multimode proximity Operations Device, and (3) Integrated Control Station. Underwater simulations carried out to determine which tasks in space should be accomplished by astronauts and which should be handled by machine are described. Knowledge derived from the EASE (Experimental Assembly of Structures in EVA) experiment is reviewed. K.K.

**A87-15191#**
**DEVELOPMENT OF A TEST PROCEDURE AND FACILITY FOR THE INVESTIGATION OF A CANADARM JOINT BRAKE ANOMALY**
J. M. TRENOUTH (National Aeronautical Establishment, Ottawa, Canada) and C. W. MACKENZIE (National Research Council of Canada, Ottawa) Canadian Aeronautics and Space Journal (ISSN 0008-2821), vol. 32, June 1986, p. 131-138.

The 15 ft Remote Manipulator System arm of the Shuttle has spring-loaded clutch-type brakes which are activated whenever power is off or whenever commanded manually. During thermal vacuum cycling qualification tests one of the brake motors suffered degradation of the slip torque and the brake failed failure to meet specifications. Full capability returned in ambient atmosphere conditions. Subsequent brake tests were performed in temperatures at 10 C intervals between -36 to +93 C and in ambient and vacuum conditions while spinning the brakes in an unloaded condition. M.S.K.

**A87-15384**
**AUTOMATION IN SERVICING OF CUSTOMER SPACECRAFT AND PLATFORMS**
E. G. GIBSON (TRW, Inc., Federal Systems Div., Redondo Beach, CA) IN: Space Station beyond IOC; Proceedings of the Thirty-second Annual International Conference, Los Angeles, CA, November 6, 7, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 95-97.
(AAS PAPER 85-470)

The applications and required technological advances for highly automated servicing of satellites and platforms from the base Space Station are described. The spacecraft could be in polar, GEO, or coorbits. Automated operations with the robotic units on an OMV would save as much as 20,000 lb in payload and would reduce the exposure of astronauts to hazardous materials such as propellants. The technologies needing development are three-dimensional color vision and machine recognition of unknown complex objects. M.S.K.

**A87-15810*#** National Aeronautics and Space Administration, Washington, D.C.
**THE EVOLUTION OF AUTOMATION AND ROBOTICS IN MANNED SPACEFLIGHT**
T. L. MOSER (NASA, Washington, DC) and J. D. ERICKSON (NASA, Johnson Space Center, Houston, TX) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 20 p. refs
(IAF PAPER 86-12)

The evolution of automation on all manned spacecraft including the Space Shuttle is reviewed, and a concept for increasing automation and robotics from the current Shuttle Remote Manipulator System (RMS) to an autonomous system is presented. The requirements for robotic elements are identified for various functions on the Space Station, including extravehicular functions and functions within laboratory and habitation modules which expand man's capacity in space and allow selected teleoperation from the ground. The initial Space Station will employ a telerobot and necessary knowledge based systems as an advisory to the crew on monitoring, fault diagnosis, and short term planning and scheduling. V.L.

**A87-15832*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**NASA'S ROBOTIC SERVICING ROLE FOR SPACE STATION**
L. POWELL, R. GOSS (NASA, Marshall Space Flight Center, Huntsville, AL), and R. SPENCER (Martin Marietta Corp., Denver, CO) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p. refs
(IAF PAPER 86-47)

Attention is given to evaluations of the relative impacts on and benefits to the Space Station Program of various levels of robotics devices for space servicing operations. The leading robotic candidate concept for the IOC Space Station, the Smart Front End, uses a small, stiff and highly dexterous work effector controlled by a human-in-the-loop from a remote control station. This configuration offers both a quality multifunctional performance capability at the work site as well as technology transparency through the ground teleoperation control mode. K.K.

**A87-15841*#** National Aeronautics and Space Administration, Washington, D.C.
**SPACE STATION AS A VITAL FOCUS FOR ADVANCING THE TECHNOLOGIES OF AUTOMATION AND ROBOTICS**
G. VARSI and D. H. HERMAN (NASA, Washington, DC) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 7 p. refs
(IAF PAPER 86-62)
The application of robotics and automation technologies to the Space Station design is examined. Experiments being conducted in the fields of autonomy and robotics, and the benefits provided by these technologies are discussed. The use of automation and robotics in the operation management, the power system, and telerobot of the Space Station is described. I.F.

**A87-15844#**
**A FEASIBILITY STUDY OF AN EXPERT SYSTEM FOR A SPACE STATION AND EXPERIMENTS IN SPACE**
T. OGINO and K. IJICHI (Mitsubishi Electric Corp., Kamakura, Japan) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p.
(IAF PAPER 86-65)
Applications of artificial intelligence to a space program including a space station project are examined from various angles. Examples of the application of an expert system to the Space Station are provided. It is concluded that an expert system can compensate for a lack of human experts by reducing the workload and increasing efficiency. It is found that this system is useful for the tracking and control of any type of satellite as well as for free flyer operation and control. K.K.

**A87-18481**
**RESEARCH AND DEVELOPMENT OF A SMALL-SIZED SPACE MANIPULATOR**
K. MACHIDA, Y. TODA, T. IWATA, K. NAKAYAMA (Ministry of International Trade and Industry, Electrotechnical Laboratory, Sakura, Japan), K. TSUCHIYA (Mitsubishi Electric Corp., Amagasaki, Japan) et al. IN: Space exploitation and utilization; Proceedings of the Symposium, Honolulu, HI, December 15-19, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 481-494. refs
(AAS PAPER 85-660)
Recent space activities require many types of manipulators or robots for assembling and servicing in space, and especially demand small-sized manipulators for dexterous tasks. A 1-meter class articulated manipulator with space environment durability and lightweight has been developed. This paper presents the system design of the manipulator and development efforts of its components. Tribological study of mechanical elements in the vacuum environment, the design of actuator with high torque-to-weight ratio, the control system with the multi-microprocessor and the dynamic control algorithm of the arm are described. A bilateral force-reflecting master-slave control system, using a six dimensional force/torque sensor of the slave arm is also discussed. Author

**A87-18486**
**ROBOTICS CONCEPTS FOR THE U.S. SPACE STATION**
D. DORROUGH (Boeing Artificial Intelligence Center, Seattle, WA) IN: Space exploitation and utilization; Proceedings of the Symposium, Honolulu, HI, December 15-19, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 539-568. refs
(AAS PAPER 85-666)
The advanced basic concepts of machine intelligence are covered that will be required to produce an operator system interface (OSI) to provide reasonable autonomy on the part of an extravehicular space-station automation. The OSI is considered for a free-flying robot that transits from one task space to another in close proximity to the earth-orbiting Space Station. The OSI would thus perform path planning, track and control, object recognition, fault detection/isolation/correction, and plan modifications in connection with the EV robot operations. To implement such an OSI implies the use of natural languages, voice recognition and synthesis, speech understanding, expert cooperative diagnostic and advisory knowledge systems, and machine learning. The latter technologies are expected to evolve through three distinct phases, where in the first phase the robot is in the primary control loop (human directed), in the second the robot is both primary controller and planner (human monitored), and in the third the robot provides its own goals (human instruction and crisis intervention). Results of Project TAARGET (Transational Assessment of Autonomous Robotic Generational and Evolutionary Technology) suggest that it will not be possible to deploy a fully autonomous EV robot and OSI by the time the Space Station is constructed in orbit. D.H.

**A87-19603*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**ARTIFICIAL INTELLIGENCE FOR SPACE STATION AUTOMATION: CREW SAFETY, PRODUCTIVITY, AUTONOMY, AUGMENTED CAPABILITY**
O. FIRSCHEIN, M. P. GEORGEFF, W. PARK, P. C. CHEESEMAN, J. GELDBERG (NASA, Advanced Technology Advisory Committee, Houston, TX; SRI International, Menlo Park, CA) et al. Research sponsored by NASA. Park Ridge, NJ, Noyes Publications, 1986, 400 p. refs
Artificial intelligence (AI) R&D projects for the successful and efficient operation of the Space Station are described. The book explores the most advanced AI-based technologies, reviews the results of concept design studies to determine required AI capabilities, details demonstrations that would indicate the existence of these capabilities, and develops an R&D plan leading to such demonstrations. Particular attention is given to teleoperation and robotics, sensors, expert systems, computers, planning, and man-machine interface. K.K.

**A87-22368#**
**OVERVIEW OF AL APPLICATIONS FOR SPACE STATION SYSTEMS MANAGEMENT**
J. F. SPITZER, D. G. HAMMEN, C. M. KELLY, C. A. MARSH, D. A. MURATORE (Mitre Corp., Houston, TX) et al. AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 12 p.
(AIAA PAPER 87-0031)
The use of artificial intelligence for operational management functions on the Space Station is studied. The control of system and fault management on the ground and on the Space Station using automation is examined. The development of an automated integrated system management composed of integrated status assessment, objective management and procedures interpreter capabilities is discussed. The functions of the integrate display and control, the integrated system management, the intergrated status assessment, the objectives management, the procedures interpreter, and the planning support environment components of the operational management system are described. I.F.

**A87-23229*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**A FLEXIBLE TELEROBOTIC SYSTEM FOR SPACE OPERATIONS**
NANCY ORLANDO SLIWA and RALPH W. WILL (NASA, Langley Research Center, Hampton, VA) Workshop on Space Telerobotics, Pasadena, CA, Jan. 20-22, 1987, Paper. 9 p.
This paper describes the objective and design of a proposed goal-oriented knowledge-based telerobotic system for space operations. This design effort encompasses the elements of the system executive and user interface and the distribution and general structure of the knowledge base, the displays, and the task sequencing. The objective of the design effort is to provide an expandable structure for a telerobotic system that provides cooperative interaction between the human operator and computer control. The initial phase of the implementation provides a rule-based, goal-oriented script generator to interface to the existing control modes of a telerobotic research system, in the Intelligent Systems Research Lab at NASA Research Center. Author

**A87-23647**
**ARTIFICIAL INTELLIGENCE HARDWARE ARCHITECTURES FOR THE SPACE STATION ERA - THE TEXAS INSTRUMENTS EXPLORER AND COMPACT LISP**
STEVE KRUEGER, GLENN MANUEL, GENE MATTHEWS, GRANVILLE OTT, and CHARLES WATKINS (Texas Instruments Inc., Computer Science Center, Dallas) Optical Engineering (ISSN 0091-3286), vol. 25, Nov. 1986, p. 1186-1193. refs
(Contract N00039-84-C-0537)

In order to deepen understanding of hardware architecture requirements for Space Station program automation, an examination is conducted of AI languages in which attention is given to the generic elements of such architectures. Beginning with simple block diagrams, and including discussions of architectural element functions, a presentation is made of LISP machines and of a state-of-the-art, proprietary workstation for them. Also noted are the features and performance of the Compact LISP embedded computer. Uniprocessor LISP machines, the potential for reduced instruction set computers, and multiprocessor AI machines are projected. O.C.

**A87-23648*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**ISSUES IN THE DESIGN OF AN EXECUTIVE CONTROLLER SHELL FOR SPACE STATION AUTOMATION**
WILLIAM K. ERICKSON and PETER C. CHEESEMAN (NASA, Ames Research Center, Moffett Field, CA) Optical Engineering (ISSN 0091-3286), vol. 25, Nov. 1986, p. 1194-1199. refs

A major goal of NASA's Systems Autonomy Demonstration Project is to focus research in artificial intelligence, human factors, and dynamic control systems in support of Space Station automation. Another goal is to demonstrate the use of these technologies in real space systems, for both round-based mission support and on-board operations. The design, construction, and evaluation of an intelligent autonomous system shell is recognized as an important part of the Systems Autonomy research program. His paper describes autonomous systems and executive controllers, outlines how these intelligent systems can be utilized within the Space Station, and discusses a number of key design issues that have been raised during some preliminary work to develop an autonomous executive controller shell at NASA Ames Research Center. Author

**A87-24708#**
**SYSTEM REQUIREMENTS AND ARCHITECTURE FOR A SPACE STATION USER END-TO-END DATA SYSTEM**
E. OLIER (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IN: Digital networks and their evolution - Space and terrestrial systems; Proceedings of the Thirty-third International Congress on Electronics and Twenty-sixth International Meeting on Space, Rome, Italy, Mar. 18-20, 1986 . Rome, Rassegna Internazionale dell'Elettronico, dell'Energia, e dello Spazio, 1986, p. 285-294. refs

The design of the end-to-end data system to be employed by the ESA Columbus module of the projected NASA Space Station is presently addressed from the viewpoint of user requirements; these extend to the demand anticipated from a projected user community, the means to its accommodation, and the technology that appears most usefully applicable to the meeting of the demand. Attention is also given to the concept of 'Telescience', which would allow scientists on earth to have desk-top access in an interactive/real time environment to mission planning, operations, sensor images, and voice and data, from the Columbus/Space Station system. O.C.

**A87-25756**
**THE ROLE OF ROBOTICS IN SPACE**
LELLAND A. C. WEAVER (Westinghouse Electric Advanced Production Technology, Ltd., Coventry, England) IN: Space Tech '86; Proceedings of the International Conference, Geneva, Switzerland, May 14-16, 1986 . London, Online International, Ltd., 1986, p. 61-67.

Consideration is given to the monitoring and maintenance of the Space Station's systems and facilities using AI and robotics. The applications of expert systems, signal processing, and voice data entry or speech recognition to the Station are discussed and examples are provided. The capabilities of the Remotely Operated Service Arm, which is based on robotic systems and AI and is to be utilized to repair the Station's systems and facilities are described. The development of the Cell Management Language to coordinate the operations of different machines and create automated factories with automated manufacturing and processing for the space Station is examined. I.F.

**A87-25757**
**A ROBOTIC SYSTEM FOR DEXTEROUS TASKS**
PIERGIOVANNI MAGNANI (Fabbrica Italiana Apparecchiature Radioelettriche S.p.A., Milan, Italy) IN: Space Tech '86; Proceedings of the International Conference, Geneva, Switzerland, May 14-16, 1986 . London, Online International, Ltd., 1986, p. 69-89.

There are a range of tasks and operative conditions in the space environment which may be efficiently managed by a 'small dimension dexterous manipulator'. The configuration of such a manipulator and its main characteristics are considered in this paper. The aspects evaluated are: articulation, position/orientation envelope working area, actuation, and sensoriality. The robotic system analyzed is suitable to be mounted on a moving frame, to be brought in the working area, and then to perform a given envelope of tasks. The moving frame can be a service manipulator arm for external space applications or a moving guide for S/C internal applications. Author

**A87-25984**
**AUTOMATION AND ROBOTICS WITH AEROSPACE APPLICATIONS**
D. O. REUDINK (AT&T Bell Laboratories, Holmdel, NJ) IN: Aerospace Applications Conference, Steamboat Springs, CO, Feb. 1-8, 1986, Digest . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, 13 p. refs

A Space Station making extensive use of automation and robotics (A&R) will be more flexible and adaptable than one incorporating fewer A&R features; it will in addition have lower operating costs, improved reliability, and greater autonomy. It is also expected to be capable of performing robot and teleoperator tasks unsuited to humans, such as the assembly of large space structures, due to the hazardous conditions to which they would be exposed. It is accordingly recommended that the NASA Space Station be used as a medium for the promotion of A&R. Attention is presently given to the development status and spinoff advantages of developments in robotic vision. O.C.

**A87-29594*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**RAISING THE AIQ OF THE SPACE STATION**
HENRY LUM (NASA, Ames Research Center, Moffett Field, CA) and EWALD HEER Aerospace America (ISSN 0740-722X), vol. 25, Jan. 1987, p. 16, 17.

Expert systems and robotics technologies are to be significantly advanced during the Space Station program. Artificial intelligence systems (AI) on the Station will include 'scars', which will permit upgrading the AI capabilities as the Station evolves to autonomy. NASA-Ames is managing the development of the AI systems through a series of demonstrations, the first, controlling a single subsystem, to be performed in 1988. The capabilities being integrated into the first demonstration are described; however, machine learning and goal-driven natural language understanding will not reach a prototype stage until the mid-1990s. Steps which

will be taken to endow the computer systems with the ability to move from heuristic reasoning to factual knowledge, i.e., learning from experience, are explored. It is noted that the development of Space Station expert systems depends on the development of experts in Station operations, which will not happen until the Station has been used extensively by crew members. M.S.K.

**A87-31112*#** National Aeronautics and Space Administration, Washington, D.C.

**SECOND AIAA/NASA USAF SYMPOSIUM ON AUTOMATION, ROBOTICS AND ADVANCED COMPUTING FOR THE NATIONAL SPACE PROGRAM**

DALE MYERS (NASA, Washington, DC) AIAA, NASA, and USAF, Symposium on Automation, Robotics and Advanced Computing for the National Space Program, 2nd, Arlington, VA, Mar. 9-11, 1987. 4 p.

(AIAA PAPER 87-1655)

An introduction is given to NASA goals in the development of automation (expert systems) and robotics technologies in the Space Station program. Artificial intelligence (AI) has been identified as a means to lowering ground support costs. Telerobotics will enhance space assembly, servicing and repair capabilities, and will be used for an estimated half of the necessary EVA tasks. The general principles guiding NASA in the design, development, ground-testing, interactions with industry and construction of the Space Station component systems are summarized. The telerobotics program has progressed to a point where a telerobot servicer is a firm component of the first Space Station element launch, to support assembly, maintenance and servicing of the Station. The University of Wisconsin has been selected for the establishment of a Center for the Commercial Development of Space, specializing in space automation and robotics. M.S.K.

**A87-31116*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**NASA SYSTEMS AUTONOMY DEMONSTRATION PROJECT - DEVELOPMENT OF SPACE STATION AUTOMATION TECHNOLOGY**

JOHN S. BULL, RICHARD BROWN, PETER FRIEDLAND, CARLA M. WONG, WILLIAM BATES (NASA, Ames Research Center, Moffett Field, CA) et al. AIAA, NASA, and USAF, Symposium on Automation, Robotics and Advanced Computing for the National Space Program, 2nd, Arlington, VA, Mar. 9-11, 1987. 11 p.

(AIAA PAPER 87-1676)

A 1984 Congressional expansion of the 1958 National Aeronautics and Space Act mandated that NASA conduct programs, as part of the Space Station program, which will yield the U.S. material benefits, particularly in the areas of advanced automation and robotics systems. Demonstration programs are scheduled for automated systems such as the thermal control, expert system coordination of Station subsystems, and automation of multiple subsystems. The programs focus the R&D efforts and provide a gateway for transfer of technology to industry. The NASA Office of Aeronautics and Space Technology is responsible for directing, funding and evaluating the Systems Autonomy Demonstration Project, which will include simulated interactions between novice personnel and astronauts and several automated, expert subsystems to explore the effectiveness of the man-machine interface being developed. Features and progress on the TEXSYS prototype thermal control system expert system are outlined. M.S.K.

**A87-31122#**

**DESIGN AND CONTROL OF MODULAR, KINEMATICALLY-REDUNDANT MANIPULATORS**

JAMES P. KARLEN, JACK M. THOMPSON, JR., and JAMES D. FARRELL (Robotics Research Corp., Milford, OH) AIAA, NASA, and USAF, Symposium on Automation, Robotics and Advanced Computing for the National Space Program, 2nd, Arlington, VA, Mar. 9-11, 1987. 12 p. refs

(AIAA PAPER 87-1694)

Design considerations, the database on robot manipulator arms and the requirements of manipulator arms for space applications are discussed. At least six degrees of freedom are needed for complete control of the position and orientation of the object held by a manipulator. For space applications, however, at least seven degrees of freedom are asserted to be necessary for general purpose manipulation systems. Four basic types of general purpose manipulator geometry are identified and the advantages of using extra joints, i.e., kinematic redundancy, in an articulated arm are described, including extra joints to permit flexibility in reaching around objects. Joint-mounted actuators are recommended for spatial volume utilization efficiency. Techniques are described for developing the motion control software architecture, and design parameters are summarized for manipulator systems for various space applications. M.S.K.

**N87-10398** Stanford Univ., Calif.

**RAPID PRECISE END POINT CONTROL OF A WRIST CARRIED BY A FLEXIBLE MANIPULATOR Ph.D. Thesis**

W. W. CHIANG 1986 141 p

Avail: Univ. Microfilms Order No. DA8612724

The speed and accuracy of a robot manipulator can be increased by using end-point sensors for motion measurement and control, along with an accurate dynamic model of the mechanical system in the control algorithm. However, the closed-loop control bandwidth of a robot manipulator is still physically limited ultimately by its structural flexibility, since the end effector and the actuator are separated. Analyses were performed to study the dynamic interaction between the motion of a minimanipulator and the structural flexibility of the main robot arm. A plane-motion mechanical system was built to demonstrate several fast maneuvers of such a mini-macro manipulator system. A frequency identification scheme was also developed and implemented successfully in a closed-loop adaptive control on a separate mechanical laboratory system consisting of two inertia disks connected by a torsional rod. It is believed that the same frequency identification scheme can be used to improve further the performance of the mini-macro manipulator system when adaptive control is employed. Dissert. Abstr.

**N87-11159*#** Stanford Univ., Calif. Dept. of Aeronautics and Astronautics.

**CONTROL OF A FREE-FLYING ROBOT MANIPULATOR SYSTEM Semiannual Report, Aug. 1985 - Feb. 1986**

H. ALEXANDER Feb. 1986 16 p

(Contract NCC2-333)

(NASA-CR-179877; NAS 1.26:179877; SAR-2) Avail: NTIS HC A02/MF A01 CSCL 05H

The development of and test control strategies for self-contained, autonomous free flying space robots are discussed. Such a robot would perform operations in space similar to those currently handled by astronauts during extravehicular activity (EVA). Use of robots should reduce the expense and danger attending EVA both by providing assistance to astronauts and in many cases by eliminating altogether the need for human EVA, thus greatly enhancing the scope and flexibility of space assembly and repair activities. The focus of the work is to develop and carry out a program of research with a series of physical Satellite Robot Simulator Vehicles (SRSV's), two-dimensionally freely mobile laboratory models of autonomous free-flying space robots such as might perform extravehicular functions associated with operation of a space station or repair of orbiting satellites. It is planned, in a later phase, to extend the research to three dimensions by carrying out experiments in the Space Shuttle cargo bay. Author

**N87-12597*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.

**AN APPROACH TO DESIGN KNOWLEDGE CAPTURE FOR THE SPACE STATION**

D. B. WECHSLER (Mitre Corp., Houston, Tex.) and K. R. CROUSE 1986 14 p

(NASA-TM-89272; NAS 1.15:89272) Avail: NTIS HC A02/MF A01 CSCL 22B

The design of NASA's space station has begun. During the design cycle, and after activation of the space station, the

reoccurring need will exist to access not only designs, but also deeper knowledge about the designs, which is only hinted in the design definition. Areas benefiting from this knowledge include training, fault management, and onboard automation. NASA's Artificial Intelligence Office at Johnson Space Center and The MITRE Corporation have conceptualized an approach for capture and storage of design knowledge. Author

**N87-13423#** Naval Postgraduate School, Monterey, Calif.
**RANGE IMAGE PROCESSING FOR LOCAL NAVIGATION OF AN AUTONOMOUS LAND VEHICLE M.S. Thesis**
D. D. POULOS Sep. 1986 206 p
(AD-A171053) Avail: NTIS HC A10/MF A01 CSCL 06D

A central emphasis for robotic research over the last few decades has been to make the systems autonomous. This implies simulating the human senses with electronic sensors and then deriving knowledge about the environment from those sensors. A large base of research exists that concentrates on computer vision algorithms that attempt to duplicate human vision. For the most part, this research has concentrated primarily on two dimensional techniques due to limitations in the available optical technology. Real time range image processing is now feasible with the introduction of the ERIM Laser Scanner as installed on the Ohio State Adaptive Suspension Vehicle (ASV). The purpose of this thesis is to utilize the three dimensional data from the Laser Scanner and by rule-based programming techniques generate a local terrain feature model for use by an Autonomous Land Vehicle. Future applications of this technology include an autonomous Lunar Rover or autonomous service/repair robots operating in close proximity to the space station. Author (GRA)

**N87-13989*#** Hamilton Standard, Hartford, Conn. Space and Sea Systems Dept.
**DEVELOPMENT OF A PRE-PROTOTYPE POWER ASSISTED GLOVE END EFFECTOR FOR EXTRAVEHICULAR ACTIVITY Final Report**
1986 26 p
(Contract NAS9-17020)
(NASA-CR-171940; NAS 1.26:171940; SVHSER-10630) Avail: NTIS HC A03/MF A01 CSCL 05H

The purpose of this program was to develop an EVA power tool which is capable of performing a variety of functions while at the same time increasing the EVA crewmember's effectiveness by reducing hand fatigue associated with gripping tools through a pressurized EMU glove. The Power Assisted Glove End Effector (PAGE) preprototype hardware met or exceeded all of its technical requirements and has incorporated acoustic feedback to allow the EVA crewmember to monitor motor loading and speed. If this tool is to be developed for flight use, several issues need to be addressed. These issues are listed. Author

**N87-14370#** Air Force Academy, Colo.
**MMU (MANNED MANEUVERING UNIT) TASK SIMULATOR Final Report, Jun. 1985 - Jan. 1986**
S. ALFANO 15 Jan. 1986 80 p
(AD-A169552; USAFA-TR-86-2) Avail: NTIS HC A05/MF A01 CSCL 22A

Described are simplified mathematical models of the Manned Maneuvering Unit (MMU) used in the USAFA Proximity Operations Simulator for the VAX 11/780 and the Evans and Sutherland PS 300 computers. This simulator serves as a learning aid for cadets studying orbital dynamics and MMU mission planning and as a research platform for the Department of Astronautics. The Manned Maneuvering Unit (MMU) Proximity Operations Simulator is a nine degrees-of-freedom trajectory integrator (six degrees of freedom for the MMU and three degrees of freedom for the target) which generates digital and graphical data to describe relative motion of the MMU and a free-flying target. This motion is obtained by applying the Clohessy-Wiltshire equations for terminal rendezvous/docking with the Earth modeled as a uniform sphere and aerodynamic forces ignored. MMU position relative to target is computed by a first-order Euler integrator which uses quaternions to define the rotational state. The target is modeled as a Space Transportation System (STS) Orbiter. The MMU is treated as a rigid body whose mass properties (gross wt., moments and products of inertia, and center of gravity location) are set within the porgram and remain constant. GRA

**N87-15260*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**MOBILE REMOTE MANIPULATOR SYSTEM FOR A TETRAHEDRAL TRUSS Patent Application**
CLARENCE J. WESSELSKI, inventor (to NASA) and WILLIAM C. SCHNEIDER, inventor (to NASA) 5 Sep. 1986 25 p
(NASA-CASE-MSC-20985-1; NAS 1.71:MSC-20985-1; US-PATENT-APPL-SN-904134) Avail: NTIS HC A02/MF A01 CSCL 22B

The mobile remote manipulator system (MRMS) was initially developed for transit about the trusses of the delta space station; however, it can be utilized just as easily for transit about the trusses of the dual keel station. The MRMS is comprised of a mobile platform B having a rail system formed of transversely disposed T-shaped tracks, which engage with guide pins located at the nodes of the trusses. The guide pins form a grid and the tracks are so designed as to permit travel in either of two orthogonal directions. For travel the MRMS is provided with retractable, reversible chain drive systems, which selectively engage sprockets on the guide pins for either longitudinal or transverse travel. The MRMS is also provided with direction changing means at the intersection of the track systems to change from longitudinal to transverse travel. The MRMS provides a near-uniform traversing velocity with minimal dynamic loading on the system. NASA

**N87-15472#** Fabrica Italiana Apparecchi Radio S.p.A., Milan.
**ROBOT SYSTEM FOR DEXTEROUS TASKS (FOR SPACE APPLICATIONS)**
PIERGIOVANNI MAGNANI 1986 16 p
(ETN-86-98562) Avail: NTIS HC A02/MF A01

A robot system for dexterous tasks in space applications, which can be mounted on a moving frame, to be brought to the working area (by the moving frame) and then perform a given envelop of tasks, is discussed. The moving frame can be a service manipulator arm (for external space applications) or a moving guide (for internal applications). ESA

**N87-16321*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**THE 20TH AEROSPACE MECHANICS SYMPOSIUM**
May 1986 316 p Symposium held in Cleveland, Ohio, 7-9 May 1986; sponsored by NASA, the California Inst. of Tech. and LMSC
(NASA-CP-2423-REV; E-2904; NAS 1.55:2423-REV) Avail: NTIS HC A14/MF A01 CSCL 20K

Numerous topics related to aerospace mechanisms were discussed. Deployable structures, electromagnetic devices, tribology, hydraulic actuators, positioning mechanisms, electric motors, communication satellite instruments, redundancy, lubricants, bearings, space stations, rotating joints, and teleoperators are among the topics covered.

**N87-17803*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**AUTOMATION, ROBOTICS, AND INFLIGHT TRAINING FOR MANNED MARS MISSIONS**
ALAN C. HOLT *In* NASA. Marshall Space Flight Center Manned Mars Mission. Working Group Papers, V. 2, Sect. 5, App. p 977-986 May 1986
Avail: NTIS HC A24/MF A01 CSCL 05I

The automation, robotics, and inflight training requirements of manned Mars missions will be supported by similar capabilities developed for the space station program. Evolutionary space station onboard training facilities will allow the crewmembers to minimize the amount of training received on the ground by providing extensive onboard access to system and experiment malfunction procedures, maintenance procedures, repair procedures, and associated video sequences. Considerable on-the-job training will

also be conducted for space station management, mobile remote manipulator operations, proximity operations with the Orbital Maneuvering Vehicle (and later the Orbit Transfer Vehicle), and telerobotics and mobile robots. A similar approach could be used for manned Mars mission training with significant additions such as high fidelity image generation and simulation systems such as holographic projection systems for Mars landing, ascent, and rendezvous training. In addition, a substantial increase in the use of automation and robotics for hazardous and tedious tasks would be expected for Mars mission. Mobile robots may be used to assist in the assembly, test and checkout of the Mars spacecraft, in the handling of nuclear components and hazardous chemical propellent transfer operations, in major spacecraft repair tasks which might be needed (repair of a micrometeroid penetration, for example), in the construction of a Mars base, and for routine maintenance of the base when unmanned. Author

**N87-18596*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**SPACE STATION ERECTABLE MANIPULATOR PLACEMENT SYSTEM Patent Application**
MARGARET E. GRIMALDI, inventor (to NASA) 13 Nov. 1986 13 p
(NASA-CASE-MSC-21096-1; NAS 1.71:MSC-21096-1; US-PATENT-APPL-SN-929865) Avail: NTIS HC A02/MF A01 CSCL 22B

A habitable space station has been proposed for low Earth orbit, to be constructed from components which will be separately carried up from the Earth and thereafter assembled. A suitable manipulating system having extraordinary manipulative capability is required. The invention is an erectable manipulator placement system for use on a space station and comprising an elongate, lattice-like boom having guide tracks attached thereto, a carriage-like assembly pivotally mounted on and extending from said dolly. The system further includes a turntable base pivotally interconnected with the proximal end of the boom and positioned either on a part of a transferring vehicle, or on another payload component being carried by said transferring vehicle, or on the space station. Novelty resides in the use of a turntable base having a hinged boom with a dolly translatable therealong to carry the arm-like assembly, thus providing an additional 3 degrees of freedom to the arm. NASA

**N87-18817*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**ORBITAL MANEUVERING END EFFECTORS Patent Application**
W. NEILL MYERS, inventor (to NASA), JOHN C. FORBES, inventor (to NASA), and WAYNE L. BARNES, inventor (to NASA) 16 Dec. 1986 12 p
(NASA-CASE-MFS-28161-1; NAS 1.71:MFS-28161-1; US-PATENT-APPL-SN-942159) Avail: NTIS HC A02/MF A01 CSCL 13I

This invention relates to an end effector device for grasping and maneuvering objects such as berthing handles of a space telescope. The device includes a V-shaped capture window defined as inclined surfaces in parallel face plates which converge toward a retainer recess in which the handle is retained. A pivotal finger (30) meshes with a pair of pivoted fingers which rotate in counterrotation. The fingers rotate to pull a handle within the capture window into recess where latches lock handle in the recess. To align the capture window, plates may be cocked plus or minus five degrees on base. Drive means is included in the form of a motor coupled with a harmonic drive speed reducer, which provides for slow movement of the fingers at a high torque so that large articles may be handled. Novelty of the invention is believed to reside in the combined intermeshing finger structure, drive means and the harmonic drive speed reducer, which features provide the required maneuverability and strength. NASA

**N87-18984*#** Grumman Aerospace Corp., Bethpage, N.Y. Space Systems Div.
**TELEROBOTIC ASSEMBLY OF SPACE STATION TRUSS STRUCTURE**
GRAHME FISCHER 1986 10 p Presented at the 1986 Space Telerobotics Workshop, Pasadena, Calif., 20-22 Jan. 1987
(Contract NAS9-17229)
(NASA-CR-180239; NAS 1.26:180239) Avail: NTIS HC A02/MF A01 CSCL 05H

Discussed are methods of assembling the space station's structure utilizing only telerobotic devices, i.e.: (1) an approximately anthropomorphic telerobot with two dextrous arms; (2) the Shuttle Remote Manipulator System (SRNS); (3) various material handling machines. Timelines and task recommendations for autonomous operations are also included. Also described are some experimental results comparing two manipulator control devices. Author

# 11

# MATERIALS

Includes mechanical properties of materials, and descriptions and analyses of different structural materials, films, coatings, bonding materials and descriptions of the effects of natural and induced space environments.

**A87-11847*** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**SPACE RADIATION EFFECTS ON THE DIMENSIONAL STABILITY OF A TOUGHENED EPOXY GRAPHITE COMPOSITE**
G. F. SYKES and D. E. BOWLES (NASA, Langley Research Center, Hampton, VA) SAMPE Quarterly (ISSN 0036-0821), vol. 17, July 1986, p. 39-45. refs

The effects of a simulated space radiation environment on the dimensional stability of an elastomer-toughened epoxy-graphite composite were determined. The response of the material was characterized following exposure to radiation doses equivalent to geosynchronous orbit lifetimes ranging from 6 months to 30 years. The results show that radiation interacts with the epoxy matrix to embrittle the composite, beginning at relatively low total doses (10 to the 7th power rads). The embrittlement results in thermal expansion changes and significant laminate microcracking during thermal cycling. These property changes could limit the service life of this material in some spacecraft applications. Author

**A87-13051*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.
**INTERNATIONAL SAMPE SYMPOSIUM AND EXHIBITION, 31ST, LOS ANGELES, CA, APRIL 7-10, 1986, PROCEEDINGS**
J. L. BAUER, ED. (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) and R. DUNAETZ, ED. (Hughes Aircraft Co., El Segundo, CA) Symposium and Exhibition sponsored by the Society for the Advancement of Material and Process Engineering. Covina, CA, Society for the Advancement of Material and Process Engineering (Science of Advanced Materials and Process Engineering Series. Volume 31), 1986, 1897 p. For individual items see A87-13052 to A87-13185.

The present conference on the development status of advanced structural materials considers topics arising in such areas as automated structural manufacturing, advanced material and structure design techniques, environmental effects on materials, composite matrix processing, computer modeling for materials and processes, materials development trends in Europe and in Japan, fiber and whisker reinforcement development status, and novel thermoplastic materials and their applications. Also discussed are pressure-sensitive adhesive systems, materials suitable for space applications, polyimide resin systems, electronic materials, novel resin chemistries, ceramic and metallic systems, and the impact performance of state-of-the-art materials. O.C.

**A87-13071**

**EFFECT OF ELECTRON-BEAM RADIATION ON GRAPHITE EPOXY COMPOSITES**

J. ENOMOT, K. NAKAZAKI, K. MURAYAMA, and K. SONODA (Mitsubishi Electric Corp., Amagasaki, Japan) IN: International SAMPE Symposium and Exhibition, 31st, Los Angeles, CA, April 7-10, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 352-361. Research sponsored by the Agency of Industrial Science and Technology. refs

Specimens of unidirectional graphite/epoxy laminates were irradiated by 10-MeV electrons up to a total dose of 5000 Mrads at 50, 150, and 250 C and then tested mechanically to determine their flexural and interlaminar shear strengths. The radiation-generated volatile products and the components extracted by a solvent from the irradiated specimens were analyzed by gas-chromatographic and mass spectrometric techniques; the degradation of the matrix resin (bisphenol based epoxy) was characterized by FT-IR spectroscopy. It is found that the flexural strength of the specimens irradiated in air decreases with increasing dose. The flexural strength of the irradiated specimens, however, can be almost completely restored through a thermal cycling treatment. It is also shown that the degradation of the matrix increases with the irradiation dose. V.L.

**A87-13097**

**THERMOPLASTIC-BASED COMPOSITES WITH LOW CTE FOR SPACE STRUCTURES AND CIRCUIT BOARD APPLICATIONS**

A. MAHAMAD IBRAHIM, T. K. SHAH, L. J. MATIENZO, and J. D. VENABLES (Martin Marietta Laboratories, Baltimore, MD) IN: International SAMPE Symposium and Exhibition, 31st, Los Angeles, CA, April 7-10, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 669-680. refs

A variety of organic and inorganic woven fabric reinforced high-performance thermoplastic composites have been investigated with a view to developing new composite systems with a low or near-zero coefficient of thermal expansion (CTE) in the X-Y direction and a reasonably low CTE in the Z direction. A high-performance semicrystalline thermoplastic, polyphenylene sulfide (PPS) has been selected as the model thermoplastic matrix system. The results obtained indicate that the use of this matrix system makes it possible to achieve more uniform thermal expansion behavior in all directions for composites used in space structures and circuit board applications. V.L.

**A87-15941#**

**ATOMIC OXYGEN SIMULATION AND ANALYSIS**

R. K. COLE, R. G. ALBRIDGE, D. J. DEAN, R. F. HAGLUND, JR. (Vanderbilt University, Nashville, TN), A. F. DAECH (Martin Marietta Corp., Michoud Div., New Orleans, LA) et al. IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 7 p. Research supported by Martin Marietta Corp. refs (IAF PAPER 86-214)

A technique has been developed for creating in the laboratory suprathermal, neutral atomic beams by means of grazing-incidence collisions between ion beams andd metal surfaces. Residual ions are either deflected or repelled by applied electric fields. The resulting neutral beams are pure, well-focused and mono-energetic. Energies from a few eV to tens of keV are obtainable. The technique permits the beams to be used in conjunction with electron and photon irradiation for studies of synergistic effects. Of particular interest is the creation of a low-energy, neutral, atomic-oxygen beam, which is of importance to space-related research. Author

**A87-18273**

**DEGRADATION OF SPACECRAFT THERMAL SHIELD MATERIALS BY IRRADIATION OF ENERGETIC PARTICLES**

M. KOITABASHI, S. SHIMOJI, T. IMAMURA, J. ENOMOTO (Mitsubishi Electric Corp., Central Research Laboratory, Amagasaki, Japan), H. KIMURA (Mitsubishi Electric Corp., Kamakura Works, Japan) et al. IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 577-582. refs

For studying the effect of the space radiation environment on silver-teflon and aluminized kapton films, the irradiations of electrons and of protons simultaneously with ultraviolet rays were performed on these films in a high vacuum condition. The solar absorptance, thermal emittance, tensile strength, and elongation rate were measured. Silver-teflon was degraded more than aluminumized kapton. The electron irradiation affected mostly the mechanical property, while the proton irradiation affected the thermooptical property. The electron irradiation created many more small molecules in the teflon film than the proton irradiation, and the double bonds between carbon atoms increased with the fluences. Author

**A87-18554**

**ELECTRICALLY CONDUCTIVE ORGANIC POLYMERS FOR ADVANCED APPLICATIONS**

D. B. COTTS and Z. REYES (SRI International, Menlo Park, CA) Research sponsored by the U.S. Air Force. Park Ridge, NJ, Noyes Data Corp., 1986, 222 p. refs

Attention is given to the properties of electrically conducting, semiconducting, and semiinsulating polymers, with a view to the conduction mechanisms involved and to the mechanical properties and space-related systems applicability of the various substances. High electron mobilities are noted to be observed only in systems that form a periodic superlattice of localized states; substances synthesized on the basis of this model are not only highly conductive but processable in organic solvents. Emphasis is given to space applications. O.C.

**A87-18867**

**MATERIALS - THE CHALLENGE OF SPACE**

G. MARSH Space (ISSN 0267-954X), vol. 2, Sept.-Nov. 1986, p. 10-12, 14, 15.

A comprehensive evaluation is made of the state of development and applicability to spacecraft structures of various advanced materials technologies, some of which are noted to have been overlooked by designers despite substantial promises of performance improvement in space environments characterized by extreme temperatures and radiation exposures. Attention is given to beryllium, lithium-aluminum and titanium alloys, carbon-carbon and ceramic composite refractories, and refractory metals, as well as space-applicable polymer-matrix composites. O.C.

**A87-19122*** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**THE EFFECTS OF RADIATION ON THE INTERLAMINAR FRACTURE TOUGHNESS OF A GRAPHITE/EPOXY COMPOSITE**

J. G. FUNK and G. F. SYKES (NASA, Langley Research Center, Hampton, VA) Journal of Composites Technology and Research (ISSN 0885-6804), vol. 8, Fall 1986, p. 92-97. refs

An experimental study is made of the effect of electron irradiation (10 to the 10th rad), simulating a 30-year geosynchronous orbit exposure, on the fracture toughness of a graphite/epoxy composite, T300/934. The double cantilever beam (DBC) test is used to determine Mode I (peel) critical strain energy release rate and the edge delamination tension (EDT) test is used to determine mixed Mode I and II (peel and shear) critical strain energy release rate. It is found that the electron interaction of the epoxy matrix material enhances the fracture toughness properties of the composite and that the test temperature has a significant effect on the fracture toughness of both baseline and irradiated material. V.L.

**A87-19342**

**USE OF GRAPHITE/EPOXY COMPOSITES IN SPACECRAFT STRUCTURES - A CASE STUDY**

R. D. JAMISON (U.S. Naval Academy, Annapolis, MD), O. H. GRIFFIN, JR. (Virginia Polytechnic Institute and State University, Blacksburg), J. A. ECKER, and W. E. SKULLNEY (Johns Hopkins University, Laurel, MD) Johns Hopkins APL Technical Digest (ISSN 0270-5214), vol. 7, July-Sept. 1986, p. 290-294. refs

The redesign of the Polar Bear satellite's center support structure is taken as a demonstration case in evaluating the applicability of graphite/epoxy composite structures for the fabrication of critical spacecraft structures. Attention is given to the results of analyses conducted for the strength, stiffness, thermal, and buckling characteristics of the support structure design. It is found that the substitution of composite for metal material is straightforward and can be accomplished with available design tools. O.C.

**A87-19343**

**EROSION STUDIES ON SOLAR MAX SAMPLES**

R. M. FRISTROM, R. C. BENSON, C. B. BARGERON, T. E. PHILLIPS, C. E. VEST (Johns Hopkins University, Laurel, MD) et al. Johns Hopkins APL Technical Digest (ISSN 0270-5214), vol. 7, July-Sept. 1986, p. 308-314.
(Contract N00024-85-C-5301)

The condition of damaged material samples from the Solar Max satellite, namely a kapton/dacron/aluminized mylar protective blanket, a piece of silver-coated teflon shielded from the sun, and another such piece of teflon that had been exposed to solar radiation, has been studied in order to infer the erosiveness of the near-space environment. Surface damage caused by high energy molecular species, submicronic micrometeorite impacts, and low energy oxygen atom erosion are discussed in light of laboratory analyses of the materials after their subjection to simulations of these processes. O.C.

**A87-20076**

**REINFORCED PLASTICS/COMPOSITES INSTITUTE, ANNUAL CONFERENCE, 41ST, ATLANTA, GA, JANUARY 27-31, 1986, PREPRINT**

Lancaster, PA, Technomic Publishing Co., 1986, 679 p. For individual items see A87-20077 to A87-20093.

The present conference on composite materials technologies encompasses topics in pultrusion techniques and products, matrix-reinforcement interface characteristics, filament winding and ply layup processes, resin curing cycles, marine applications, and reinforced thermoplastics. Also discussed are reaction injection molding processes, transportation applications, product markets, fillers and additives, testing methods, sheet molding compounds, corrosion prevention, design methods, basic research and development topics, and structural applications. O.C.

**A87-20082#**

**EFFECTS OF THERMAL CYCLING ON THE MECHANICAL AND PHYSICAL PROPERTIES OF A SPACE QUALIFIED EPOXY ADHESIVE**

J. A. SANBORN and D. E. MOREL, JR. (Harris Corp., Government Systems Sector, Melbourne, FL) IN: Reinforced Plastics/Composites Institute, Annual Conference, 41st, Atlanta, GA, January 27-31, 1986, Preprint . Lancaster, PA, Technomic Publishing Co., 1986, 5 p.

Structural adhesives used for space applications must be able to survive large temperature fluctuations while maintaining their mechanical strength. This paper describes a series of experiments performed to document property degradation of EA 956 epoxy due to temperature extremes experienced in the orbital environment. Testing included tension, lap shear, coefficient of thermal expansion (CTE) and differential scanning calorimetry (DSC). CTE data indicate that the exact value of strength decrease depends strongly on temperature; three distinct regions are observed when sample strain is plotted as a function of temperature with the CTE increasing with increasing temperature. DSC traces on as cast and thermally cycled samples show that thermal cycling produces a change in the physical structure of the resin resulting in a significant increase in the glass transition temperature of the network. Author

**A87-20144**

**INTERNATIONAL WEEK ON BONDING AND JOINING TECHNOLOGIES, 1ST, BORDEAUX, FRANCE, APRIL 15-18, 1986, SELECTED PAPERS**

Week organized by Adhecom. International Journal of Adhesion and Adhesives (ISSN 0143-7496), vol. 6, Oct. 1986, 72 p. For individual items see A87-20145 to A87-20151.

Papers are presented on bonding composites, stress analysis at the interface in adhesive joints by special finite elements, and the analysis of adhesive-bonded structural joints in space vehicles. Consideration is given to adhesive bonding of aerospace materials, modeling the elementary mechanisms involved in grafting polymers onto metals, and the use of the wedge test to estimate the lifetime of an adhesive joint in an aggressive environment. Other subjects include the physicochemical characterization of aluminum alloy surfaces after sulfochromic pickling prior to bonding, and intrinsic mechanical characterization of structural adhesives. I.S.

**A87-20148**

**BEHAVIOURAL ANALYSIS OF ADHESIVE-BONDED STRUCTURAL JOINTS IN SPACE VEHICLES**

J.-P. MAIGRET and M. MARTIN (Aerospatiale, Saint-Medard-en-Jalles, France) International Journal of Adhesion and Adhesives (ISSN 0143-7496), vol. 6, Oct. 1986, p. 189-198. refs

In space structures, the design of adhesive-bonded joints generally involves a very low safety ratio. This requires careful choice of the criteria applied to account for external factors (mechanical, static and dynamic, and thermal effects). The situation is complicated by the behavior of the materials involved, particularly composites, which undergo large distortions, and whose fracture criteria depend on load cycles. In addition, polymerization effects in joints between different materials, such as metals and composites, must also be taken into account. In this paper a calculation tool is presented for bonded structures, and procedures for the accurate determination of the mechanical properties of adhesive materials are given. Author

**A87-21992*** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**ELECTRON-RADIATION EFFECTS ON THE AC AND DC ELECTRICAL PROPERTIES AND UNPAIRED ELECTRON DENSITIES OF THREE AEROSPACE POLYMERS**

SHEILA ANN T. LONG, EDWARD R. LONG, JR. (NASA, Langley Research Center, Hampton, VA), HEIDI R. RIES, and WYNFORD L. HARRIES (Old Dominion University, Norfolk, VA) (IEEE, DNA, Sandia National Laboratories, and NASA, 1986 Annual Conference on Nuclear and Space Radiation Effects, 23rd, Providence, RI, July 21-23, 1986) IEEE Transactions on Nuclear Science (ISSN 0018-9499), vol. NS-33, Dec. 1986, pt. 1, p. 1390-1395. refs

The effects of gigarad-level total absorbed doses from 1-MeV electrons on the post-irradiation alternating-current (ac) and direct-current (dc) electrical properties and the unpaired electron densities have been studied for Kapton, Ultem, and Mylar. The unpaired electron densities (determined from electron paramagnetic resonance spectroscopy) and the dc electrical conductivities of the irradiated materials were monitored as functions of time following the exposures to determine their decay characteristics at room temperature. The elevated-temperature ac electrical dissipations of the Ultem and Mylar were affected by the radiation. The dc conductivity of the Kapton increased by five orders of magnitude, while the dc conductivities of the Ultem and Mylar increased by less than an order of magnitude, due to the radiation. The observed radiation-generated changes in the ac electrical dissipations are explained in terms of known radiation-generated changes in the molecular structures of the three materials. A preliminary model relating the dc electrical conductivity and the unpaired electron density in the Kapton is proposed. Author

**A87-22417*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**EFFECT OF HARD PARTICLE IMPACTS ON THE ATOMIC OXYGEN SURVIVABILITY OF REFLECTOR SURFACES WITH TRANSPARENT PROTECTIVE OVERCOATS**

DANIEL A. GULINO (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 8 p. Previously announced in STAR as N87-11838. refs

(AIAA PAPER 87-0104)

Silver mirror samples with protective coatings were subjected to a stream of 27 microns alumina particles to induce pinhole defects. The protective coating consisted of a layer of aluminum dioxide over silver followed by a layer of silicon dioxide over the alumina. Samples were prepared on both graphite-epoxy composite and fused quartz substrates. After exposure to the hard particle stream, the samples were exposed to an oxygen plasma environment in a laboratory plasma asher. The effects of both the hard particles and the oxygen plasma were documented by both reflectance measurements and scanning electron microscopy. The results indicated that oxidative damage to the silver reflecting layer continues beyond that of the erosively exposed silver. Oxidative undercutting of the silver layer and graphite-epoxy substrate continues in undamaged areas through adjacent, particle damaged defect sites. This may have implications for the use of such mirrors in a space station solar dynamic power system. Author

**A87-23702*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**PROPERTIES AND POTENTIAL APPLICATIONS OF BROMINATED P-100 CARBON FIBERS**

D. A. JAWORSKE, J. R. GAIER, C. C. HUNG, and B. A. BANKS (NASA, Lewis Research Center, Cleveland, OH) SAMPE Quarterly (ISSN 0036-0821), vol. 18, Oct. 1986, p. 9-14. refs

A review of the properties and potential applications of bromine-intercalated pitch-based carbon fibers is presented. The dynamics of the intercalation reaction are summarized, and characteristics, such as resistivity, density, and stability, are discussed. In addition, the mechanical and electrical properties of bromine-intercalated fiber-epoxy conposites will be addressed. With conductivities comparable to stainless steel, these brominated carbon fibers may be used in a number of composite applications, such as electromagnetic interference shielding containers, large conductive space structures, lightning strike-tolerant aircraft surfaces, and aircraft deicing applications. Author

**A87-27107*** Auburn Univ., Ala.

**A STUDY OF THE DAMPING CAPACITY OF GRAPHITE EPOXY COMPOSITES IN A VACUUM**

MOHAN D. RAO, MALCOLM J. CROCKER, G. H. ZHU, and P. K. RAJU (Auburn University, AL) IN: Inter-noise 86 - Progress in noise control; Proceedings of the International Conference on Noise Control Engineering, Cambridge, MA, July 21-23, 1986. Volume 1 . Poughkeepsie, NY, Noise Control Foundation, 1986, p. 687-692. refs

(Contract NAS8-36146)

The damping properties of a graphite epoxy composite material (used in the construction of the Hubble Space Telescope) are measured under a variety of conditions in a vacuum chamber to simulate conditions in space. An improved method is proposed which utilizes several points of the response curve near a resonance to estimate the damping ratio and the undamped resonance frequency. The damping of a graphite epoxy tube is monitored for four weeks to study moisture desorption and temperature effects. A significant variation is observed in the damping ratio with temperature. K.K.

**A87-27178*** Virginia Polytechnic Inst. and State Univ., Blacksburg.

**SPACE RADIATION EFFECTS ON THE THERMO-MECHANICAL BEHAVIOR OF GRAPHITE-EPOXY COMPOSITES**

SCOTT M. MILKOVICH, CARL T. HERAKOVICH (Virginia Polytechnic Institute and State University, Blacksburg), and GEORGE F. SYKES (NASA, Langley Research Center, Hampton, VA) Journal of Composite Materials (ISSN 0021-9983), vol. 20, Nov. 1986, p. 579-593. refs

(Contract NAG1-343)

This investigation of composite material properties utilized T300/934 graphite-epoxy that was subjected to 1.0 MeV electron radiation for a total dose of 1.0 x 10 to the 10th rads at a rate of 5.0 x 10 to the 7th rads/hour, simulating a worst-case exposure equivalent to 30 years in space. Mechanical testing was performed on 4-ply unidirectional laminates over the temperature range of -250 F (116 K) to +250 F (394 K). In-plane elastic tensile and shear properties as well as strength were obtained. The results show that electron radiation degrades the epoxy matrix and produces products that volatilize at the temperatures considered. These degradation products plasticize the epoxy at elevated temperatures and embrittle it at low temperatures, thereby altering the mechanical properties of the composite. Author

**A87-31300*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**THE SURVIVABILITY OF LARGE SPACE-BORNE REFLECTORS UNDER ATOMIC OXYGEN AND MICROMETEOROID IMPACT**

DANIEL A. GULINO (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 9 p. Previously announced in STAR as N87-14423. refs

(AIAA PAPER 87-0341)

Solar dynamic power system mirrors for use on Space Station and other spacecraft flown in low earth orbit (LEO) are exposed to the harshness of the LEO environment. Both atomic oxygen and micrometeoroids/space debris can degrade the performance of such mirrors. Protective coatings will be required to protect oxidizable reflecting media, such as silver and aluminum, from atomic oxygen attack. Several protective coating materials have been identified as good candidates for use in this application. The durability of these coating/mirror systems after pinhole defects have been inflicted during their fabrication and deployment or through micrometeoroid/space debris impact once on-orbit is of concern. Studies of the effect of an oxygen plasma environment on protected mirror surfaces with intentionally induced pinhole defects have been conducted at NASA Lewis and are reviewed. It has been found that oxidation of the reflective layer and/or the substrate in areas adjacent to a pinhole defect, but not directly exposed by the pinhole, can occur. Author

**N87-10934#** Societe Nationale Industrielle Aerospatiale, Cannes (France).

**SPACE TECHNOLOGIES AND MATERIALS: A LOOK BACK AND FUTURE PERSPECTIVES [TECHNOLOGIES ET MATERIAUX SPATIAUX: RETROSPECTIVE ET PERSPECTIVES D'AVENIR]**

J. A. MASSONI and J. L. CECCONI *In* ESA Proceedings of an International Conference on Spacecraft Structures p 347-351 Apr. 1986 In FRENCH

Avail: NTIS HC A19/MF A01

The evolution in satellite construction materials from aluminum alloys to carbon-resin structures is discussed. Future applications of metal matrix composites, aluminum-lithium composites, and silicon carbide reinforced aluminum composites are examined. ESA

**N87-10935#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. for Structural Mechanics.
**PERFORMANCE CHARACTERISTICS OF COMPOSITE MATERIALS**
H. W. BERGMANN, M. GAEDKE, and H. C. GOETTING *In* ESA Proceedings of an International Conference on Spacecraft Structures p 353-359 Apr. 1986
Avail: NTIS HC A19/MF A01

Allowable stresses for multidirectional laminates with arbitrary stacking orders are predicted analytically using the characteristics of unidirectional plies established by test. The forecast properties for static tension loading include first ply failure and ultimate strength and take into account the state of prestress induced by widely varying environmental conditions. In laminates mechanically fatigued at $R = 0.1$ the influences of temperature and moisture are shown to be moderate. In matrix-controlled laminates, elevated temperature and moisture saturation degrade the fatigue strength, while in fiber-controlled laminates the presence of moisture tends to be beneficial. In multidirectional laminates the slopes of the delta-N curves are essentially unaffected in various hot-wet conditions. Matrix-controlled laminates subjected to severe thermal cycling exhibit strength and stiffness degradations depending on the brittleness of the matrix systems. Moderate to severe matrix cracking is observed. ESA

**N87-10949#** Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Dept. d'Etudes et de Rech. en Technol. Spatiale.
**DESIGN IMPROVEMENT AND RADIATION, CONTAMINATION TESTS. PRESTUDY 1: ULTRAVIOLET RADIATION ACCELERATION, VOLUME 1 Final Report [AMELIORATION ET ESSAIS: CONTAMINATION PLUS IRRADIATION. PREETUDE 1: ACCELERATION DES IRRADIATIONS ULTRAVIOLETTES. TOME 1: ESSAIS ET CONCLUSIONS]**
J. MARCO, P. MILLAN, A. PAILLOUS, C. SABLE, and J. SIFFRE Paris ESA Dec. 1985 92 p In FRENCH
(Contract ESTEC-5781/83-NL-AB)
(CERT-4193-VOL-1; CERT-419300/PR1/T01-DERTS; ESA-CR(P)-2227-VOL-1; ETN-86-98105) Avail: NTIS HC A05/MF A01

The influence of increasing the ultraviolet radiation intensity on the degradation of satellite thermal control surface coatings is studied. Several materials were insolated for the equivalent of 1000 solar hours with intensities 2 to 8 times stronger than the radiation of the Sun, at wavelengths under 400 nm. Visible light and infrared radiation were filtered out. The materials include white paints, aluminized kapton, black paints, aluminum paints, and silver coatings. The results are extremely variable, the absorption spectra vary with the degradation of the coating, and the degradation at the higher intensities is not always greater than at relatively low intensities. ESA

**N87-10950#** Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Dept. d'Etudes et de Rech. en Technol. Spatiale.
**DESIGN IMPROVEMENT AND RADIATION CONTAMINATION TESTS. PRESTUDY 1: ULTRAVIOLET RADIATION ACCELERATION. VOLUME 2: APPENDIX, DETAILED RESULTS Final Report [AMELIORATION ET ESSAIS: CONTAMINATION PLUS IRRADIATION. PREETUDE 1: ACCELERATION DES IRRADIATIONS ULTRAVIOLETTES. TOME 2: ANNEXES, RESULTATS DETAILLES]**
J. MARCO, P. MILLAN, A. PAILLOUS, C. SABLE, and J. SIFFRE Paris ESA Dec. 1985 200 p In FRENCH
(Contract ESTEC-5781/83-NL-AB)
(CERT-4193-VOL-2; ESA-CR(P)-2227-VOL-2; ETN-86-98106)
Avail: NTIS HC A09/MF A01

The influence of increasing ultraviolet radiation intensity on the degradation of satellite thermal control surface coatings is studied. Several materials were insolated for the equivalent of 1000 hr with intensities 2 to 8 times stronger than the radiation of the Sun, at wavelengths under 400 nm. Visible light and infrared were filtered out. The materials included white paints, aluminized Kepton, black paints, alinum paints and silver coatings. The results are extremely variable, the absorption spectra vary with the degradation of the coating, and the degradation at the higher intensities is not always greater than at relatively low intensities. ESA

**N87-10951#** Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Dept. d'Etudes et de Rech. en Technol. Spatiale.
**IMPROVING THE IRRADIATION PLUS CONTAMINATION TESTS. PRESTUDY 2: SUCCESSIVE IRRADIATIONS AND SYNERGICS. VOLUME 1: TESTS AND CONCLUSIONS Final Report [AMELIORATION ET ESSAIS: CONTAMINATION PLUS IRRADIATION. PREETUDE 2: IRRADIATIONS SUCCESSIVES ET SYNERGIE. TOME 1: ESSAIS ET CONCLUSIONS]**
J. MARCO, P. MILLAN, A. PAILLOUS, C. SABLE, and J. SIFFRE Paris ESA Dec. 1985 65 p In FRENCH
(Contract ESTEC-5781/83-NL-AB)
(CERT-4193-VOL-3; CERT-419300/PR2/T01-DERTS; ESA-CR(P)-2227-VOL-3; ETN-86-98107) Avail: NTIS HC A04/MF A01

A simulation of 1 yr exposure to a geosynchronous orbit space environment was carried out. Ultraviolet radiation, protons, and electrons acted on surface coatings used on satellite thermal control equipment. The low sensitivity of the optical measurement prevents quantitative comparison. Nevertheless, observations regarding degradable materials are included. ESA

**N87-10952#** Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Dept. d'Etudes et de Rech. en Technol. Spatiale.
**IMPROVING RADIATION PLUS CONTAMINATION TESTS. PRESTUDY 2: SUCCESSIVE IRRADIATIONS AND SYNERGICS. VOLUME 2: ANNEXES. ANNEX 1: DETAILED RESULTS. ANNEX 2: CONTROL AND IMPROVEMENT OF OPTICAL MEASUREMENTS Final Report [AMELIORATION ET ESSAIS: CONTAMINATION PLUS IRRADIATION. PREETUDE 2: IRRADIATIONS SUCCESSIVES ET SYNERGIE. TOME 2: ANNEXES. ANNEXE 1: RESULTATS DETAILLES. ANNEXE 2: CONTROLE ET AMELIORATION DES MESURES OPTIQUES]**
J. MARCO, P. MILLAN, A. PAILLOUS, C. SABLE, and J. SIFFRE Paris ESA Dec. 1985 63 p In FRENCH
(Contract ESTEC-5781/83-NL-AB)
(CERT-4193-VOL-4; ESA-CR(P)-2227-VOL-4; ETN-86-98108)
Avail: NTIS HC A04/MF A01

A simulation of 1 yr exposure to a geosynchronous orbit space environment was carried out. Ultraviolet radiation, protons and electrons were used on surface coatings employed on satellite thermal control equipment. The low sensitivity of the optical measurements precludes a quantitative comparison. Nevertheless, observations regarding degradable materials are included. ESA

**N87-10954#** Office National d'Etudes et de Recherches Aerospatiales, Toulouse (France). Dept. d'Etudes et de Rech. en Technol. Spatiales.
**IMPROVING RADIATION/CONTAMINATION TESTS Final Report [AMELIORATION DES ESSAIS: CONTAMINATION PLUS IRRADIATION]**
J. MARCO and A. PAILLOUS Paris ESA Jul. 1985 95 p In FRENCH
(Contract ESTEC-5781/83-NL-AB)
(CERT-419300/1-DERTS; ESA-CR(P)-2245; ETN-86-98123; PS-4)
Avail: NTIS HC A05/MF A01

The characteristics of optical fibers in the wavelengths from 300 to 2500 nm are studied in order to define an improved optical spectral measuring instrument able to determine in situ the reflection factor of satellite coatings. The measuring system would have fixed samples and movable detector (optical fibers) in a high vacuum environment. A detailed study of optical fiber bundles is included. Energy balance of different systems using fibers is compared. Possible solutions are examined concluding that improved systems based on the use of optical fibers are feasible. ESA

**N87-10960*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**OXIDATION-RESISTANT REFLECTIVE SURFACES FOR SOLAR DYNAMIC POWER GENERATION IN NEAR EARTH ORBIT**

D. A. GULINO, R. A. EGGER (Cleveland State Univ., Ohio), and W. F. BANHOLZER (General Electric Co., Schenectady, N. Y.) 1986 16 p Presented at the 33rd National Symposium of the National Vacuum Society, Baltimore, Md., 27-31 Oct. 1986

(NASA-TM-88865; E-3268; NAS 1.15:88865) Avail: NTIS HC A02/MF A01 CSCL 10B

Reflective surfaces for space station power generation systems are required to withstand the atomic oxygen-dominated environment of near Earth orbit. Thin films of platinum and rhodium, which are corrosion resistant reflective metals, have been deposited by ion beam sputter deposition onto various substrate materials. Solar reflectances were then measured as a function of time of exposure to a RF-generated air plasma. Similarly, various protective coating materials, including MgF2, SiO2, Al2O3, and Si3N4, were deposited onto silver-coated substrates and then exposed to the plasma. Analysis of the films both before and after exposure by both ESCA and Auger spectroscopy was also performed. The results indicate that Pt and Rh do not suffer any loss in reflectance over the duration of the tests. Also, each of the coating materials survived the plasma environment. The ESCA and Auger analyses are discussed as well. Author

**N87-10977*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

**THE EFFECTS OF SPACE RADIATION ON A CHEMICALLY MODIFIED GRAPHITE-EPOXY COMPOSITE MATERIAL Interim Report**

S. M. REED (Virginia Polytechnic Inst. and State Univ., Blacksburg), C. T. HERAKOVICH, and G. F. SYKES Oct. 1986 97 p

(Contract NAG1-343)

(NASA-TM-89232; NAS 1.15:89232; CCMS-86-06; VPI-E-86-19; IR-60) Avail: NTIS HC A05/MF A01 CSCL 11D

The effects of the space environment on the engineering properties and chemistry of a chemically modified T300/934 graphite-epoxy composite system are characterized. The material was subjected to 1.0 x 10 to the 10th power rads of 1.0 MeV electron irradiation under vacuum to simulate 30 years in geosynchronous earth orbit. Monotonic tension tests were performed at room temperature (75 F/24 C) and elevated temperature (250 F/121 C) on 4-ply unidirectional laminates. From these tests, inplane engineering and strength properties (E sub 1, E sub 2, Nu sub 12, G sub 12, X sub T, Y sub T) were determined. Cyclic tests were also performed to characterize energy dissipation changes due to irradiation and elevated temperature. Large diameter graphite fibers were tested to determine the effects of radiation on their stiffness and strength. No significant changes were observed. Dynamic-mechanical analysis demonstrated that the glass transition temperature was reduced by 50 F(28 C) after irradiation. Thermomechanical analysis showed the occurrence of volatile products generated upon heating of the irradiated material. The chemical modification of the epoxy did not aid in producing a material which was more radiation resistant than the standard T300/934 graphite-epoxy system. Irradiation was found to cause crosslinking and chain scission in the polymer. The latter produced low molecular weight products which plasticize the material at elevated temperatures and cause apparent material stiffening at low stresses at room temperature. Author

**N87-11838*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**EFFECT OF HARD PARTICLE IMPACTS ON THE ATOMIC OXYGEN SURVIVABILITY OF REFLECTOR SURFACES WITH TRANSPARENT PROTECTIVE OVERCOATS**

D. A. GULINO 1986 22 p Proposed for presentation at the 25th Aerospace Sciences Meeting, Reno, Nev. 12-15 Jan. 1987; sponsored by the American Institute of Aeronautics and Astronautics

(NASA-TM-88874; E-3281; NAS 1.15:88874) Avail: NTIS HC A02/MF A01 CSCL 10B

Silver mirror samples with protective coatings were subjected to a stream of 27 microns alumina particles to induce pinhole defects. The protective coating consisted of a layer of aluminum dioxide over silver followed by a layer of silicon dioxide over the alumina. Samples were prepared on both graphite-epoxy composite and fused quartz substrates. After exposure to the hard particle stream, the samples were exposed to an oxygen plasma environment in a laboratory plasma asher. The effects of both the hard particles and the oxygen plasma were documented by both reflectance measurements and scanning electron microscopy. The results indicated that oxidative damage to the silver reflecting layer continues beyond that of the erosively exposed silver. Oxidative undercutting of the silver layer and graphite-epoxy substrate continues in undamaged areas through adjacent, particle damaged defect sites. This may have implications for the use of such mirrors in a space station solar dynamic power system. Author

**N87-12601#** California Univ., Los Angeles. Dept. of Materials Science and Engineering.

**NEW MATERIALS FOR SPACECRAFT STABILITY AND DAMPING: A FEASIBILITY STUDY Final Technical Report, 1 Oct. 1983 - 30 Sep. 1984**

J. D. MACKENZIE Nov. 1985 52 p

(Contract AF-AFOSR-0221-83)

(AD-A169826; AFOSR-86-0308TR) Avail: NTIS HC A04/MF A01 CSCL 11D

A preliminary feasibility study has been conducted on some new materials for use as structure components of spacecrafts. These included some new glasses, glass-ceramics, fibers and composites such as low expansion copper aluminosilicate glasses, hollow and oval glass fibers and hollow fiber-glass-polymer composites. The low temperature expansion coefficients, elastic moduli and damping constants were measured. Recommendations are made for further research and development of some selected materials which appeared to be promising candidates for spacecraft structures. GRA

**N87-13572#** United Kingdom Atomic Energy Authority, Harwell (England). Polymer and Composites Group.

**DEVELOPMENT OF A CONTINUOUS MANUFACTURING METHOD FOR A CFRP COLLAPSIBLE TUBE MAST Final Report**

D. H. BOWEN, R. DAVIDSON, R. J. LEE, and T. THORPE Jun. 1986 105 p

(Contract ESTEC-6106/84/NL/AN(SC))

(AERE-G-3898; HL86/1252(C14)) Avail: NTIS HC A06/MF A01

A sequential molding process was developed for forming continuous lengths of profiled carbon fiber reinforced plastic (CFRP) sheet, and for the edge-bonding of two identical profiles to produce a lenticular-shaped collapsible tube mast (CTM). The process was designed to enable a wide range of CTM sizes, characterized by the shape radius r, to be produced, and it will accept either thermosetting or thermoplastic matrix composites. The Tube Manufacturing Method (TMM) was proved by the construction of a laboratory scale rig and its use to produce continuously 10 m lengths of mast profile of uniform section and surface finish. The mechanical properties of the fabrics impregnated with the two resins were measured to provide basic tube mast design data. Viscoelastic relaxations in both types of composites were determined after storing sections of mast profile in the flattened condition over periods of time as a function of temperature. Author

**N87-14374*#** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
**PROCEEDINGS OF THE SMRM DEGRADATION STUDY WORKSHOP**
1985 351 p Workshop held in Greenbelt, Md., 9-10 May 1985
(NASA-TM-89274; REPT-408-SMRM-79-0001; NAS 1.15:89274)
Avail: NTIS HC A16/MF A01 CSCL 22B

The proceedings of the Solar Maximum Repair Mission Degradation Study Workshop, held at the Goddard Space Flight Center in Greenbelt, Maryland on May 9 to 10, 1985 are contained. The results of tests and studies of the returned Solar Maximum Mission hardware and materials are reported. Specifically, the workshop was concerned with the effects of four years' exposure to a low-Earth orbit environment. To provide a background for the reported findings, the summary includes a short description of the Solar Maximum Mission and the Solar Maximum Repair Mission.

**N87-14383*#** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
**RESULTS OF EXAMINATION OF MATERIALS FROM THE SOLAR MAXIMUM RECOVERY MISSION**
J. J. PARK *In its* Proceedings of the SMRM Degradation Study Workshop p 211-226 1985
Avail: NTIS HC A16/MF A01 CSCL 22B

Four years and two months in space at 310 nautical miles orbit has produced different effects on Kapton, silver/Teflon, and on aluminum. Kapton, a polyimide, lost up to 31% in thickness, though other locations showed much less loss. The degradation of silver/Teflon was drastic but very localized, due perhaps to the formation of silver oxide, Ag2O, through cracks in the protective Inconel layer which exposed the silver to the oxygen atom environment. Penetrations of the thin aluminum sheet in the form of thermal louvers and also of the thermal blanket material due to unknown particles were unexpected, making the debris a potentially serious problem because of the threat of damage to components.
Author

**N87-14384*#** Johns Hopkins Univ., Laurel, Md. Applied Physics Lab.
**STUDIES OF EROSION OF SOLAR MAX SAMPLES OF KAPTON AND TEFLON**
R. M. FRISTROM, R. C. BENSON, C. B. BARGERON, T. E. PHILLIPS, C. E. VEST, C. H. HOSHALL, F. G. SATKIEWICZ, and O. M. UY *In* NASA. Goddard Space Flight Center Proceedings of the SMRM Degradation Study Workshop p 227-242 1985
Avail: NTIS HC A16/MF A01 CSCL 22B

Several samples of Kapton and Teflon which was exposed to solar radiation were examined. The samples represent material behavior in near Earth space. Clues to the identity of erosive processes and the responsible species were searched for. Interest centered around oxygen atoms which are ubiquitous at these altitudes and are known to erode some metal surfaces. Three diagnostic methods were employed: optical microscopy, scanning electron microscopy, and fourier transform infrared spectroscopy. Two types of simulation were used: a flow containing low energy oxygen atoms and bombardment with 3000 volt Ar ions. Results and conclusions are presented.
E.R.

**N87-14385*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**ANALYSIS OF MICROMETEORITE MATERIAL CAPTURED BY THE SOLAR MAX SATELLITE**
L. S. SCHRAMM (Lockheed Engineering and Management Services Co., Inc., Houston, Tex.), D. S. MCKAY, H. A. ZOOK, and G. A. ROBINSON *In* NASA. Goddard Space Flight Center Proceedings of the SMRM Degradation Study Workshop p 243-244 1985
Avail: NTIS HC A16/MF A01 CSCL 22B

A Solar Maximum satellite was retrieved and repaired after being subjected for four years and 55 days to impacts by micrometeorites and Earth-orbiting space debris. The chemical variety and physical condition of particles associated with two particular impact structures in the insulation blanket of the main electronics box are studied. A scanning electron microscope equipped with an energy dispersive X ray analyzer was used to determine morphology and chemistry of impacted areas and associated particles. Some details are discussed.
E.R.

**N87-14387*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**A PRELIMINARY REPORT ON THE STUDY OF THE IMPACT SITES AND PARTICLES OF THE SOLAR MAXIMUM SATELLITE THERMAL BLANKET**
H. A. ZOOK *In* NASA. Goddard Space Flight Center Proceedings of the SMRM Degradation Study Workshop p 247-264 1985
Avail: NTIS HC A16/MF A01 CSCL 22B

A preliminary study of the work on examination of the impact pits in, or penetrations through, the thermal blankets of the Solar Maximum Satellite is presented. The three largest pieces of the thermal blanket were optically scanned with a total surface area of about one half square meter. Over 1500 impact sites of all sizes, including 432 impacts larger than 40 microns in diameter, have been documented. Craters larger in diameter than about 100 microns found on the 75 micron thick Kapton first sheet of the main electronics box blanket are actually holes and constitute perforations through the blanket. A summary of the impact pit population that were found is given. The chemical study of these craters is only in the initial stages, with only about 250 chemical spectra of particles observed in or around impact pits or in the debris pattern being recorded.
E.R.

**N87-14388*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**SSM ATOMIC OXYGEN REACTIONS ON KAPTON AND SILVERIZED TEFLON**
R. LINTON and A. WHITAKER *In* NASA. Goddard Space Flight Center Proceedings of the SMRM Degradation Study Workshop p 265-272 1985
Avail: NTIS HC A16/MF A01 CSCL 22B

Surface morphology studies using scanning electron microscopy on Kapton and Inconel silver coated Teflon material samples retrieved from the Solar Maximum Mission spacecraft revealed significant changes attributed to orbital atomic oxygen induced reactions. The Kapton recession observed on the aluminized Kapton material samples appeared equivalent in nature with that observed on previous Space Shuttle LEO missions. SSM Teflon taped material samples, coated on the back side with films of Inconel protected silver were observed degraded on both sides. Visibly severe reactions on the back side produced total blackening, generally restricted to areas of tape with a narrow direct view-factor of the external orbital environment. High magnification scanning electron microscope views provided evidence of near total silver reaction, flaking, and subsequent erosion of the underlying Teflon itself. Only three of the extensive S.E.M. photographs illustrating the basic reactions observed are included pending further detailed investigations.
E.R.

**N87-14389*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**PRELIMINARY RESULTS OF SMM EXPOSED ALUMINIZED KAPTON AND SILVERED TEFLON**
B. SANTOS-MASON *In* NASA. Goddard Space Flight Center Proceedings of the SMRM Degradation Study Workshop p 273-286 1985
Avail: NTIS HC A16/MF A01 CSCL 22B

Early Space Shuttle flights revealed that organic materials, such as those used in thermal control blankets and paints in the payload bay, were adversely affected in the low Earth orbit environment. Examination of eroded surfaces on these early flights and materials experiments performed on subsequent flights led to the conclusion that atomic oxygen present at Shuttle operating altitudes was responsible for surface degradation. The Solar Maximum Mission provided surfaces that had been exposed in real time to atomic oxygen and ultraviolet radiation. Preliminary results of studies of the microscopic surface effects on silvered Teflon and aluminized Kapton used for thermal control on the Solar Maximum Mission are presented.
E.R.

**N87-14391*#** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
**ANALYSIS OF NORMAL AND TRANSPARENT SILVER TEFLON**
W. K. STUCKEY, A. A. GALUSKA, and J. UHT *In its* Proceedings of the SMRM Degradation Study Workshop p 317-336 1985
Avail: NTIS HC A16/MF A01 CSCL 22B

Samples of Inconel/silver/Teflon exposed to solar radiation, and atomic oxygen on Solar Max were microcharacterized. Those samples exposed to atomic oxygen from the metallic side had become transparent while those exposed from the Teflon side remained reflective. The difference between the transparent and non-transparent material was determined. Microcharacterization of these Inconel/silver/Teflon samples was performed using scanning electron microscopy with windowless energy dispersive X ray analysis, secondary ion mass spectrometry, and X ray photoelectron spectroscopy. Author

**N87-14392*#** Jet Propulsion Lab., California Inst. of Tech., Pasadena. Applied Mechanics Technology Section.
**DEGRADATION STUDIES OF SMRM TEFLON**
R. H. LIANG, K. L. ODA, and S. Y. CHUNG *In* NASA. Goddard Space Flight Center Proceedings of the SMRM Degradation Study Workshop p 337-342 1985
Avail: NTIS HC A16/MF A01 CSCL 22B

A working group was organized to study materials and components of the Solar Max Satellite (SMS) that was returned by the STS 41C. These materials were exposed in space for 50 months and represent the only real time long term exposure data available to date. In the molecular modeling of material and energetic oxygen atom interaction, it is pointed out that the importance of developing correlation between accelerated exposure data from STS and some real time data. In particular, it was predicted that Teflon which showed no detectable degradation on various STS flights may be susceptible to atomic oxygen degradation under real time conditions. Initial inspection of returned SMS samples showed that Teflon suffered visual damage such as cracking and yellowing. The results of examination of these samples are given. Author

**N87-14423*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**THE SURVIVABILITY OF LARGE SPACE-BORNE REFLECTORS UNDER ATOMIC OXYGEN AND MICROMETEOROID IMPACT**
D. A. GULINO 1987 18 p Presented at the 25th Aerospace Sciences Meeting, Reno, Nev., 12-15 Jan. 1987; sponsored by AIAA
(NASA-TM-88914; E-3338; NAS 1.15:88914) Avail: NTIS HC A02/MF A01 CSCL 21H

Solar dynamic power system mirrors for use on space station and other spacecraft flown in low Earth orbit (LEO) are exposed to the harshness of the LEO environment. Both atomic oxygen and micrometeoroids/space debris can degrade the performance of such mirrors. Protective coatings will be required to protect oxidizable reflecting media, such as silver and aluminum, from atomic oxygen attack. Several protective coating materials have been identified as good candidates for use in this application. The durability of these coating/mirror systems after pinhole defects have been inflicted during their fabrication and deployment or through micrometeoroid/space debris impact once on-orbit is of concern. Studies of the effect of an oxygen plasma environment on protected mirror surfaces with intentionally induced pinhole defects have been conducted at NASA Lewis and are reviewed. It has been found that oxidation of the reflective layer and/or the substrate in areas adjacent to a pinhole defect, but not directly exposed by the pinhole, can occur. Author

**N87-16015*#** Ametek, Inc., Anaheim, Calif. Composite Materials and Applications Div.
**ADVANCED COMPOSITES FOR LARGE NAVY SPACECRAFT**
WILLIAM E. DAVIS *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 1-10 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 11D

An overview is given of work conducted on contract for the Naval Sea Systems Command. The objective of this contract was to provide direction for the development of high modulus graphite reinforced metal matrix composites. These advanced materials can have a significant effect on the performance of a spacecraft before, during and after an evasive maneuver. The work conducted on this program was organized into seven technical tasks. Task 1 was development of a generic Navy spacecraft model. Finite element models of candidate structural designs were developed. In Task 2, the finite-element model(s) of the structure were used to conduct analytical assessments involving conventional materials, resin matrix composites and metal matrix composites (MMC). In Task 3 and 4, MMC material design, fabrication and evaluation was conducted. This consisted of generating material designs and developing a data base for a broad range of graphite reinforced MMC materials. All material was procured according to specifications which set material quality and material property standards. In Task 5, a set of evasive maneuvering requirements were derived and used in Task 6 to conduct analytical simulations. These analytical simulations used current SOA material properties and projected material properties to provide an indication of key payoffs for material development. In Task 7, a set of material development recommendations was generated. Author

**N87-17863#** Martin Marietta Aerospace, Denver, Colo.
**METALLURGICAL CHARACTERIZATION OF THE INTERFACES AND THE DAMPING MECHANISMS IN METAL MATRIX COMPOSITES Progress Report, 1 Oct. 1985 - 30 Sep. 1986**
MOHAN S. MISRA 30 Sep. 1986 5 p
(Contract N00014-84-C-0413)
(AD-A173470; MCR-85-605-ISSUE-4) Avail: NTIS HC A02/MF A01 CSCL 11D

High inherent damping is a material property requirement to meet the need for dynamic dimensional precision and weight savings in space structures. A preliminary investigation indicates that MMC exhibit improved damping with respect to conventional structural alloys of aluminum or titanium. In the present investigation, a graphite-aluminum composite (P55/6061) has been selected to study the microstructural features and mechanisms responsible for damping in MMC. During this investigation, methodology to measure damping by clamped free flexure and uniaxial tension-tension test techniques were developed. Work conducted within the reporting period: (1) Preliminary results with free-free flexure indicate that this method can be used sucessfully to measure damping in metal matrix composites; (2) TEM of Gr/Al composites show that the dislocations adjacent to the fiber matrix interface are thermal expansion mismatch of the fiber and matrix during the fabrication process; (3) Strain amplitude dependent damping is the result of dislocation motion and correlates well with the Granato-Lucke theory of dislocation damping. GRA

**N87-17906*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**TRIBOLOGICAL PROPERTIES OF POLYMER FILMS AND SOLID BODIES IN A VACUUM ENVIRONMENT**
ROBERT L. FUSARO 1987 34 p Prepared for presentation at the Annual Meeting of the American Society of Lubrication Engineers, Anaheim, Calif., 11-14 May 1987
(NASA-TM-88966; E-3429; NAS 1.15:88966) Avail: NTIS HC A03/MF A01 CSCL 11B

The tribological properties of ten different polymer based materials were evaluated in a vacuum environment to determine their suitability for possible lubrication applications in a space environment, such as might be encountered on the proposed space station. A pin-on-disk tribometer was used and the polymer materials were evaluated either as solid body disks or as films

applied to 440C HT stainless steel disks. A 440C HT stainless steel hemispherically tipped pin was slid against the polymer materials. For comparison, similar tests were conducted in a controlled air atmosphere of 50 percent relative humidity air. In most instances, the polymer materials lubricated much better under vacuum conditions than in air. Thus, several of the materials show promise as lubricants for vacuum applications. Friction coefficients of 0.05 or less and polymer material wear rates of up to 2 orders of magnitude less than in air were obtained. One material showed considerable promise as a traction drive material. Relatively high friction coefficients (0.36 to 0.52) and reasonably low wear rates were obtained in vacuum. Author

**N87-18613*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**SEAMLESS METAL-CLAD FIBER-REINFORCED ORGANIC MATRIX COMPOSITE STRUCTURES AND PROCESS FOR THEIR MANUFACTURE Patent Application**
RAYMOND M. BLUCK, inventor (to NASA) (Lockheed Missiles and Space Co., Sunnyvale, Calif.), HAROLD G. BUSH, inventor (to NASA), and ROBERT R. JOHNSON, inventor (to NASA) 21 Oct. 1986 10 p
(NASA-CASE-LAR-13562-1; NAS 1.71:LAR-13562-1; US-PATENT-APPL-SN-921572) Avail: NTIS HC A02/MF A01 CSCL 11D

The invention relates to seamless metal clad filament reinforced resin matrix composite tubular structures and processes for their manufacture and is particularly useful in the construction of spacecraft and space structures. Metal clad composites make a significant advancement over those composite systems being used for both spacecraft and aircraft; however, the material consolidation and tooling advances necessary to realize the potential of such metal clad composites had not hitherto been achieved. Accordingly, it is an object of this invention to provide an efficient method of producing seamless metal clad composite structures. A metallic outer sleeve is provided which is capable of enveloping a hollow metallic inner member having continuous reinforcing fibers attached to the distal end thereof. Inner member is then introduced into outer sleeve until inner member is completely enveloped by outer sleeve. A liquid matrix material is then injected into the space between inner member and outer sleeve. A pressurized heat transfer medium is flowed through the inside of inner member, thereby forming a fiber reinforced matrix composite material. The wall thicknesses of both inner member and outer sleeve are then reduced to the appropriate size by chemical etching, to adjust the thermal expansion coefficient of the metal-clad composite structure to the desired value. The novelty of this invention resides in the development of a efficient method of producing seamless metal clad fiber reinforced organic matrix composite structures. NASA

**N87-19457#** Materials Sciences Corp., Spring House, Pa.
**THERMOVISCOELASTIC CHARACTERIZATION AND ANALYSIS OF FIBER COMPOSITE SPACE STRUCTURES Final Report, 1 Oct. 1984 - 31 Dec. 1985**
B. J. SULLIVAN, E. A. HUMPHREYS, and ZVI HASHIN Feb. 1986 170 p
(Contract F49620-85-C-0004)
(AD-A175024; MSC-TFR-1614/1505; AFOSR-86-2111TR) Avail: NTIS HC A08/MF A01 CSCL 11D

This report begins with the development of the time and temperature-dependent effective constitutive equations for unidirectional fiber composites. The fibers were represented as transversely isotropic and linearly elastic, temperature dependent elements. The deviatoric components of the isotropic matrix material were treated as linearly viscoelastic and thermorheologically complex, while the dilatation components were represented as elastic and temperature dependent. Numerical simulations of a series of isothermal creep tests were performed to determine the effective creep compliance parameters of the composite constitutive equations. The macromechanical response of a composite structural element, as predicted by the effective constitutive equations and their derived parameters, was then verified using results computed using a micromechanical model which explicitly included the fiber and matrix as discrete phases. To determine the potential existence and form of a composite complex modulus, the response of unidirectional composite structural elements to simultaneous sinusoidal temperature and mechanical loads was investigated. Finally, solutions of free vibration and transient dynamic analyses of some simple composite structures were performed to examine the effects of the thermoviscoelastic behavior on the damped response of some simple composite structures. GRA

# 12

# INFORMATION AND DATA MANAGEMENT

Includes descriptions, requirements, and trade studies of different information and data system hardware and software, languages, architecture, processing and storage requirements for managing and monitoring of different systems and subsystems.

**A87-10051*** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**SPACE STATION DATA MANAGEMENT SYSTEM ASSESSMENT METHODOLOGY**
W. R. JONES (NASA, Langley Research Center, Hampton, VA) and D. L. BAHRS (Computer Sciences Corp., Silver Spring, MD) IN: Space Congress, 23rd, Cocoa Beach, FL, April 22-25, 1986, Proceedings . Cape Canaveral, FL, Canaveral Council of Technical Societies, 1986, p. 11-1 to 11-6.

A computer-aided modeling tool and methodology was developed and is currently being used to assess candidate designs for the Space Station Data Management System (DMS). The DMS will be a complex distributed computer system including processors, storage devices, local area networks, and software that will support all processing functions on board the Space Station. The methodology produces assessments of the performance, reliability, cost, and physical attributes of the candidate designs. This paper describes the architecture and design of the modeling tool and presents the modeling methodology. Author

**A87-16003#**
**THE CONSULTATIVE COMMITTEE FOR SPACE DATA SYSTEMS (CCSDS) PLANNED AND POTENTIAL USE OF THE RECOMMENDATIONS**
H. KUMMER (ESA, European Space Operations Centre, Darmstadt, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p. refs
(IAF PAPER 86-303)

The CCSDS has, with the participation of most of the world's major space agencies, established a number of important recommendations for space data system standards. The activities cover: (1) radiometric, i.e., tracking and flight dynamics data, (2) standard format data units for data transfer, archiving and retrieval and (3) data structures and operation procedures for telemetry, command, timing and radio frequency systems. The paper covers the progress of work in this last group of topics and in particular, the acceptance and application of the recommendations in the planning of the infrastructure and projects of the CCSDS participating agencies. One outstanding example in this context is the U.S. Space Station with Canadian, European and Japanese participation, all four also supporting CCSDS activities. Author

**A87-18852**
**AEROSPACE COMPUTER SECURITY CONFERENCE, 2ND, MCLEAN, VA, DECEMBER 2-4, 1986, TECHNICAL PAPERS**
Conference sponsored by AIAA, American Society for Industrial Security, and DOD Computer Institute. New York, American Institute of Aeronautics and Astronautics, 1986, 142 p. For individual items see A87-18853 to A87-18865.

Papers are presented on a model for the containment of computer viruses, the Commercial Communications Security

Endorsement Program, and a design for a multilevel secure database management system. Topics discussed include secure computer systems, electronic mail privacy enhancement, multilevel data storage design, and secure database management system architectural analysis. Particular attention is given to access control and privacy in large distributed systems and the verification of integrity. I.F.

**A87-18860#**

**STRAWMAN DEFINITION FOR THE SPACE STATION INFORMATION SYSTEM NETWORK SECURITY**

A. WHITE (Intermetrics, Inc., Huntington Beach, CA) IN: Aerospace Computer Security Conference, 2nd, McLean, VA, December 2-4, 1986, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1986, p. 86-94. refs
(AIAA PAPER 86-2780)

The 'Strawman Definition for the Space Station Information System Network Security' provides an initial look at the security measures proposed for the Space Station Program. The paper analyzes security issues facing the design of the Space Station. A network security model for the Space Station Information System is introduced and security objectives are established. Recommendations for Space Station security are proposed to protect NASA and its customers. The paper serves as a baseline for further discussion. Author

**A87-23076*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.

**NATURAL LANGUAGE INTERFACE FOR COMMAND AND CONTROL**

ROBERT L. SHULER, JR. (NASA, Johnson Space Center, Houston, TX) IN: 1986 Summer Computer Simulation Conference, Reno, NV, July 28-30, 1986, Proceedings . San Diego, CA, Society for Computer Simulation, 1986, p. 784-789. refs

A working prototype of a flexible 'natural language' interface for command and control situations is presented. This prototype is analyzed from two standpoints. First is the role of natural language for command and control, its realistic requirements, and how well the role can be filled with current practical technology. Second, technical concepts for implementation are discussed and illustrated by their application in the prototype system. It is also shown how adaptive or 'learning' features can greatly ease the task of encoding language knowledge in the language processor. Author

**A87-24701**

**DIGITAL NETWORKS AND THEIR EVOLUTION - SPACE AND TERRESTRIAL SYSTEMS; PROCEEDINGS OF THE THIRTY-THIRD INTERNATIONAL CONGRESS ON ELECTRONICS AND TWENTY-SIXTH INTERNATIONAL MEETING ON SPACE, ROME, ITALY, MAR. 18-20, 1986**

Conference supported by the Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, CNR, ESA, et al. Rome, Rassegna Internazionale dell'Elettronica, dell'Energia, e dello Spazio, 1986, 474 p. For individual items see A87-24702 to A87-24712.

Among the topics presently discussed are the position of space and terrestrial systems in digital communications network evolution, research and experiments on broadband subscriber networks in Italy, ESA satellite communications activities and plans, research on the integrated switching of voice and video transmissions, advanced structures for digital broadband switching, and the use of Banyan networks for high throughput switching exchanges. Also considered are the interconnection of digital systems with different standards, standard compatibility of ISND terminals, the global plan for network layer addressing in open systems interconnection, videoconferencing, ISND and office automation, intelligent networks, the European Data Relay Satellite, the Space Station's data systems, and Columbus communications. O.C.

**A87-25977**

**A DESIGN APPROACH FOR THE SPACE STATION DATA SYSTEM**

ELAINE VOLANSKY and CHARLES ROBERTS (TRW, Inc., TRW Defense Systems Group, Redondo Beach, CA) IN: Aerospace Applications Conference, Steamboat Springs, CO, Feb. 1-8, 1986, Digest . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, 17 p. refs

The Space Station Data System (SSDS) furnishes user command management services for shared and/or limited flight resources such as electrical power, thermal dissipation, and attitude position. The SSDS design approach presented is fully integrated, along the following lines: (1) the space and ground network node is viewed as a single entity; (2) standardized interfaces to this node are provided for all users, payloads, and platforms; and (3) a data-driven network node is responsive to data as it is received. The primary means to implementation of this design approach is the Data Delivery Service, which provides communication intelligence, space/ground core/user integration, and end-to-end transparent user access. O.C.

**A87-25981**

**SPACE STATION MULTI-PURPOSE APPLICATIONS CONSOLE**

MICHAEL A. DONOVAN and BRIAN L. MASSON (Hughes Aircraft Co., El Segundo, CA) IN: Aerospace Applications Conference, Steamboat Springs, CO, Feb. 1-8, 1986, Digest . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, 16 p.

This paper will describe in detail the trade study approach taken in the concept definition and preliminary design of the Multi-Purpose Applications Console (MPAC) for the Space Station system. Discussion will be limited to the fixed (stationary) console design. Attention is given to the MPAC man-machine interface criteria. Author

**A87-27607#**

**WHEN IS LOGISTIC DATA REALLY INTEGRATED OR HOW TO AVOID THE 'TOWER OF BABEL' SYNDROME?**

STANFORD E. HOFFMAN (McDonnell Douglas Astronautics Co., Rockville, MD) IN: Space Logistics Symposium, 1st, Huntsville, AL, Mar. 24-26, 1987, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1987, p. 21-26.
(AIAA PAPER 87-0661)

The Space Station will be a long-duration mission, which presents maintenance problems that must be considered in logistics analysis during design. The distribution of project work among four main U.S. contractors and foreign contractors, all coordinated by NASA, will necessitate an automated data system that can be equally accessed by all participants. The data management function, growth accommodation techniques, security considerations, and compatibility requirements of the data system, which will be routed through NASA links, are explored. NASA must set standards for displays, languages and data element representations. MIL-STD-1388-2A is recommended as a guideline in order to obtain a disciplined structure for logistics data in the data system. M.S.K.

**A87-30416#**

**DATA MANAGEMENT FOR FUTURE SPACE PROJECTS**

FRANZ PITTERMANN Dornier Post (English Edition) (ISSN 0012-5563), no. 3, 1986, p. 34-37.

Necessary features of a data management system (DMS) suitable for large-scale future space projects are examined. The European Columbus project is to consist of several subsystems: a manned pressurized module which is attached to the U.S. Space Station; a man-tended free flyer (MTFF) which is composed of a smaller pressurized module and a resource module, with the MTFF able to fly separated from the Space Station and be visited by astronauts for short times; and unmanned free-flying platforms. A suitable DMS would consist of modular subsystems with each module replaceable without interrupting system functions. At a minimum, it would have to be a fail-safe system. Ultimately, DMS development would permit automatic initialization and verification of rendezvous and docking of different spacecraft, replacement of

components by robots, repairs, and maintenance. For the spacecraft, the DMS would assume the role of mission planning and control. Components discussed include: computer; interconnection link; data memories; and crew interface. Aspects of the required software technology are considered. D.H.

**A87-31121#**
**SOFTWARE ARCHITECTURE FOR MANUFACTURING AND SPACE ROBOTICS**
J. S. ALBUS, R. LUMIA, and H. MCCAIN (NBS, Robot Systems Div., Gaithersburg, MD) AIAA, NASA, and USAF, Symposium on Automation, Robotics and Advanced Computing for the National Space Program, 2nd, Arlington, VA, Mar. 9-11, 1987. 11 p. refs
(AIAA PAPER 87-1687)

A hierarchical architecture is described which supports Space Station telerobots in a variety of modes. The system is divided into three hierarchies: task decomposition, world model, and sensor processing. Goals at each level of the task decomposition hierarchy are divided both spatially and temporally into simpler commands for the next lower level. This decomposition is repeated until, at the lowest level, the drive signals to the robot actuators are generated. To accomplish its goals, task decomposition modules must often use information stored in the world model. The purpose of the sensory system is to update the world model as rapidly as possible to keep the model in registration with the physical world. This paper describes the architecture of the entire control system hierarchy and how it can be applied to space telerobot applications. Author

**N87-10928#** Royal Netherlands Aircraft Factories Fokker, Amsterdam. Space Div.
**ENGINEERING AND SOFTWARE INTERFACING FOR THERMAL, STRUCTURAL AND ATTITUDE CONTROL RELATED WITH SPACECRAFT**
J. J. WIJKER, H. GEYSELAERS, and A. C. M. VANSWIETEN *In* ESA Proceedings of an International Conference on Spacecraft Structures p 305-313 Apr. 1986
(Contract ESTEC-5158/82-NL-PB(SC))
Avail: NTIS HC A19/MF A01

The engineering and software interfaces between the finite element package ASKA, the dynamic and control analysis package DCAP, and the thermal analysis program SINDA are presented. The engineering background of interface programs IFDCAP and SINAS is discussed. ESA

**N87-12581*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**SOLAR ARRAY FLIGHT DYNAMIC EXPERIMENT**
R. W. SCHOCK Washington May 1986 27 p
(NASA-TP-2598; NAS 1.60:2598) Avail: NTIS HC A03/MF A01 CSCL 10A

The purpose of the Solar Array Flight Dynamic Experiment (SAFDE) is to demonstrate the feasibility of on-orbit measurement and ground processing of large space structures dynamic characteristics. Test definition or verification provides the dynamic characteristic accuracy required for control systems use. An illumination/measurement system was developed to fly on space shuttle flight STS-31D. The system was designed to dynamically evaluate a large solar array called the Solar Array Flight Experiment (SAFE) that had been scheduled for this flight. The SAFDE system consisted of a set of laser diode illuminators, retroreflective targets, an intelligent star tracker receiver and the associated equipment to power, condition, and record the results. In six tests on STS-41D, data was successfully acquired from 18 retroreflector targets and ground processed, post flight, to define the solar array's dynamic characteristic. The flight experiment proved the viability of on-orbit test definition of large space structures dynamic characteristics. Future large space structures controllability should be greatly enhanced by this capability. Author

**N87-16033*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**MAST FLIGHT SYSTEM OPERATIONS**
M. LARRY BRUMFIELD *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 299-317 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 20K

The integration process of the MAST flight system is surveyed. Insight is given into the planned orbital experiment process. The data flow necessary to support the flight operation is outlined. Author

**N87-16761*#** Oakwood Coll., Huntsville, Ala. Dept. of Business and Information Systems Management.
**AN EVALUATION OF THE DOCUMENTED REQUIREMENTS OF THE SSP UIL AND A REVIEW OF COMMERCIAL SOFTWARE PACKAGES FOR THE DEVELOPMENT AND TESTING OF UIL PROTOTYPES**
ESTHER NAOMI GILL *In* NASA. Marshall Space Flight Center Research Reports: 1986 NASA/ASEE Summer Faculty Fellowship Program 36 p Nov. 1986
Avail: NTIS HC A99/MF E04 CSCL 09B

A review was conducted of software packages currently on the market which might be integrated with the interface language and aid in reaching the objectives of customization, standardization, transparency, reliability, maintainability, language substitutions, expandability, portability, and flexibility. Recommendations are given for best choices in hardware and software acquisition for inhouse testing of these possible integrations. Software acquisition in the line of tools to aid expert-system development and/or novice program development, artificial intelligent voice technology and touch screen or joystick or mouse utilization as well as networking were recommended. Other recommendations concerned using the language Ada for the user interface language shell because of its high level of standardization, structure, and ability to accept and execute programs written in other programming languages, its DOD ownership and control, and keeping the user interface language simple so that multiples of users will find the commercialization of space within their realm of possibility which is, after all, the purpose of the Space Station. Author

**N87-16769*#** New Mexico State Univ., University Park.
**BENCHMARKS OF PROGRAMMING LANGUAGES FOR SPECIAL PURPOSES IN THE SPACE STATION**
ARTHUR KNOEBEL *In* NASA. Marshall Space Flight Center Research Reports: 1986 NASA/ASEE Summer Faculty Fellowship Program 29 p Nov. 1986
Avail: NTIS HC A99/MF E04 CSCL 09B

Although Ada is likely to be chosen as the principal programming language for the Space Station, certain needs, such as expert systems and robotics, may be better developed in special languages. The languages, LISP and Prolog, are studied and some benchmarks derived. The mathematical foundations for these languages are reviewed. Likely areas of the space station are sought out where automation and robotics might be applicable. Benchmarks are designed which are functional, mathematical, relational, and expert in nature. The coding will depend on the particular versions of the languages which become available for testing. Author

**N87-16873*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**INITIAL UTILIZATION OF THE CVIRB VIDEO PRODUCTION FACILITY**
RUSSELL V. PARRISH, ANTHONY M. BUSQUETS, and THOMAS W. HOGGE Feb. 1987 46 p
(NASA-TM-89036; NAS 1.15:89036) Avail: NTIS HC A03/MF A01 CSCL 14B

Video disk technology is one of the central themes of a technology demonstrator workstation being assembled as a man/machine interface for the Space Station Data Management Test Bed at Johnson Space Center. Langley Research Center personnel involved in the conception and implementation of this workstation have assembled a video production facility to allow

production of video disk material for this propose. This paper documents the initial familiarization efforts in the field of video production for those personnel and that facility. Although the entire video disk production cycle was not operational for this initial effort, the production of a simulated disk on video tape did acquaint the personnel with the processes involved and with the operation of the hardware. Invaluable experience in storyboarding, script writing, audio and video recording, and audio and video editing was gained in the production process. Author

**N87-16948#** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Mechanical Systems Div.

**ENGINEERING AND SOFTWARE INTERFACING FOR THERMAL, STRUCTURAL AND DYNAMIC CONTROL RELATED WITH SPACECRAFT ACTIVITIES**

C. STAVRINIDIS, M. KLEIN, and J. WIJKER (Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost) *In its* Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 219-225 Aug. 1986
(Contract ESTEC-5158/82-NL-PB(SC))
Avail: NTIS HC A12/MF A01

Engineering practices and information needed by the different spacecraft disciplines, and the possibilities of coupling thermal, structural, and attitude control analysis programs are discussed. Implementation of identified and developed methods for specific interfaces is described. Engineering and software interfaces between the finite element package ASKA and the dynamic control analysis package DCAP, and between the thermal analysis program SINDA and the finite element package ASKA are presented. The software for the corresponding interface programs are identified as IFDCAP and SINAS. ESA

**N87-19000*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.

**TAVERNS AND THE SPACE STATION SOFTWARE SUPPORT ENVIRONMENT**

NORMAN R. HOWES (Lockheed Engineering and Management Services Co., Inc., Houston, Tex.) and GARY K. RAINES 1987 6 p Proposed for presentation at the ADA Europe 87 Conference, Stockholm, Sweden, 26-28 May 1987
(NASA-TM-89280; NAS 1.15:89280) Avail: NTIS HC A02/MF A01 CSCL 09B

The Space Station Information System (SSIS) provides the data processing capability for the Space Station Program (SSP). The Software Support Environment (SSE) System for the SSP is the collection of software, procedures, standards, hardware specification, documentation, policy, and training materials. The Ada programming language was baselined by the Space Station Program Office as the language for development and maintenance of all space station software including the software of the SSE itself. The Test And Validation Environment for Remote Networked Systems (TAVERNS) is a distributed philosophy for development and validation of Ada applications software for the space station and as such is closely related to the SSE. An overview of the system is provided. B.G.

# 13

# ACCOMMODATIONS

Includes descriptions of simulations, analyses, trade studies, and requirements for safe efficient procedures, facilities, and support equipment on the ground and in space for processing, servicing, maintenance, reliability, commonality, verification and checkout of cargo and equipment.

**A87-10037*** National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, Fla.

**SPACE STATION GROUND PROCESSING**

E. J. SCULLY (NASA, Kennedy Space Center; McDonnell Douglas Astronautics Co., Cocoa Beach, FL) IN: Space Congress, 23rd, Cocoa Beach, FL, April 22-25, 1986, Proceedings . Cape Canaveral, FL, Canaveral Council of Technical Societies, 1986, p. 4-22 to 4-39. refs

The architecture of the Station, the system requirements, and the operational capabilities for ground and flight operations are described. The proposed Space Station design is dual keel and the components of the Station are listed. The initial ground processing activities are to reflect the on-orbit assembly sequence; the four phases of the assembly are examined. The planning and analysis for the ground processing of the Station with an emphasis on cost are discussed. The logistics resupply elements aspect of the ground processing sequence is considered. An example testing the capabilities of the ground processing sequence is presented. Diagrams of the Shuttle, its modules, and ground facilities and equipment are provided. I.F.

**A87-10545**

**SAFE ACCESS TO PRESSURISED HABITABLE SPACES**

O. P. HARWOOD British Interplanetary Society, Journal (Space Technology) (ISSN 0007-084X), vol. 39, Aug. 1986, p. 353-356.

Several design approaches are discussed that would allow safe human transfer between space vehicles and modules of the Space Station (SS). Airlines have substantial experience in protecting personnel in pressurized compartments similar to those which will be implemented on the SS. For example, it is known that round doors leak the least on the ends of cylindrical compartments, and that doors on the sides of cylinders always leak. It is recommended that equipment that must pass through airlocks be designed to fit through safe airlocks, rather than increasing the size of airlocks to accommodate larger equipment such as the MMU. Consideration is given to the methods of interconnecting modules to ensure gradual degradation instead of failure, and to selecting doors which do not impede passage through an airlock. A simplified design of a two-piece, integrally machined door with bayonet locking attachments similar to those on camera lenses is proposed as a candidate SS component. M.S.K.

**A87-13431*** Illinois Univ., Urbana.

**AUTOMATIC DECOUPLING OF FLEXIBLE SPACECRAFT SLEWING MANEUVERS**

T. A. W. DWYER, III (Illinois, University, Urbana) IN: 1986 American Control Conference, 5th, Seattle, WA, June 18-20, 1986, Proceedings. Volume 3 . New York, Institute of Electrical and Electronics Engineers, 1986, p. 1529-1534. refs
(Contract NSF ECS-85-16445; NAG1-436)

The capability for large angle slewing maneuvers with very demanding pointing accuracy and tracking speed is increasingly required for space-based systems. This is particularly the case for space-based directed energy beam pointing. A method is thus proposed in this paper for commanding general pointing and tracking maneuvers with automatic correction for slew-excited structural deformations. All existing rigid body multiaxial slewing algorithms and flexible body vibration damping algorithms can then be used simultaneously, without design iterations. In particular, an example is given of a retargeting maneuver with specified line-of-sight settling time and no torque saturation. Author

**A87-15405**
**R&M IN A SYSTEMATIC TRADE STUDY PROCESS**
H. E. ZEBICK and M. G. HOERSTER (General Dynamics Corp., San Diego, CA) IN: 1986 Annual Reliability and Maintainability Symposium, Las Vegas, NV, January 28-30, 1986, Proceedings . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, p. 61-68. refs

This paper describes the effort to ensure the involvement of reliability and maintainability early in the design process of spaced-based systems. The challenge of evolving from a ground-oriented approach to an on-orbit capability is discussed. The development of a systematic trade study methodology is delineated. The inclusion of reliability and maintainability as key components of the design/trade study process is addressed. Details of the process and materials used are provided. Author

**A87-15406**
**GUIDELINES FOR SPACE STATION MAINTAINABILITY**
R. L. SMITH and S. E. SMITH (Otha C. Jean and Associates, Inc., Huntsville, AL) IN: 1986 Annual Reliability and Maintainability Symposium, Las Vegas, NV, January 28-30, 1986, Proceedings . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, p. 69-76.

Principles to guide space Station reliability and on-orbit maintainability are described. It is recommended that the design of parts to be used throughout the Station be standardized at the earliest possible date, including latches and fasteners, tools and equipment, and connections for fluids and electrical circuits. Orbital replacement units (ORUs) must be removable and replaceable without causing the system being repaired to fail. Where possible, means must be provided to bypass the failed component and still retain full system operability. M.S.K.

**A87-18131**
**AN EXPERT SYSTEM FOR DYNAMIC SCHEDULING**
S. FLOYD and D. FORD (Alabama, University, Huntsville) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1795-1800.

The development of a solution procedure and interactive system for scheduling subsystems and payloads/experiments for the National Aeronautics and Space Administration Space Station program is presented in this paper. Traditional scheduling problems are static in nature and have one or more clearly defined objectives. These problems are most commonly solved via application of optimal seeking algorithms, heuristics or simulation analysis. The payload scheduling problem, in contrast, is highly dynamic in nature. Not only may the various parameters change at any time but the objectives themselves may change also. As will be illustrated in this paper, the nature of this class of problems is such that they can be most effectively solved by knowledge-based expert systems. Author

**A87-28130**
**SPACE STATION PAYLOAD ACCOMMODATION**
T. C. AEPLI and U. R. ALVARADO (General Research Co., Space Systems Div., Philadelphia, PA) IEEE Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 2, Jan. 1987, p. 13-17.

The unique characteristics of the Space Station are changing the ways payloads are designed and accommodated for orbital flight. Station accommodations need to be versatile and operationally flexible to permit integration of many types of equipment in a variety of modes; and autonomous to render each payload independent or invisible to the rest of the system and other mission equipment. This paper presents the various categories of Space Station payloads, the user facilities that are being designed to accommodate them, illustrates through scientific and commercial scenarios the utilization of those facilities, and identifies the factors that must be considered to make the Space Station an effective tool for the users. Author

**A87-29455#**
**RATIONALE FOR A SPACE STATION PROPULSION SYSTEM TEST BED**
CLAYTON W. WILLIAMS (Aerojet TechSystems Co., Sacramento, CA) IN: Aerospace Testing Seminar. 9th. Los Angeles. CA. Oct. 15-17, 1985, Proceedings . Mount Prospect, IL, Institute of Environmental Sciences, 1986, p. 116-124.

The Space Station propulsion system test bed program is a phased demonstration of Space Station technologies being conducted by the Marshall Space Flight Center. Program objectives consider unique station requirements such as closed-loop operation, long life, health monitoring and control, on-orbit maintenance, low cost earth to orbit logistics, and establishing bases for minimum development risk. Much has been learned about development risk reduction at Aerojet which is applicable to the test bed program. From the LOX/RP-1 and Gemini Titan family, the Apollo SPS, Titan Transtage, and Space Shuttle OMS engine to the recent second stage Delta/N-II test bed and flight propulsion systems, successively less risky development programs have been conducted. These are reviewed and pertinent component, system, and operational experience are extracted and analyzed. The Space Station propulsion system test bed is shown as a logical beneficiary of these and other liquid rocket development experiences. Author

**N87-10910#** Technische Hochschule, Aachen (West Germany). Inst. fuer Leichtbau.
**TRANSIENT EXTERNAL LOADS OR INTERFACE FORCES RECONSTRUCTED FROM STRUCTURAL RESPONSE MEASUREMENTS**
H. OERY, H. GLASER, and D. HOLZDEPPE *In* ESA Proceedings of an International Conference on Spacecraft Structures p 171-177 Apr. 1986 Sponsored by Deutsche Forschungsgemeinschaft and MBB GmbH
Avail: NTIS HC A19/MF A01

The procedure for the reconstruction of transient forcing functions based on measured structural responses during former flights is described, i.e., the inverse problem of the dynamic response is investigated. The method is developed on the basis of the combination and inversion of the phase-plane-method, which delivers modal responses and the Williams method, which separates the pure dynamic and the quasistatic parts of structural responses. Criteria influencing the reconstruction of the impulsive active load and its time-history are discussed. For a spacecraft transported by a launcher the interface motion time-history must be defined. ESA

**N87-16917*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**RESEARCH OPPORTUNITIES IN MICROGRAVITY SCIENCE AND APPLICATIONS DURING SHUTTLE HIATUS**
BRUCE N. ROSENTHAL, THOMAS K. GLASGOW, RICHARD E. BLACK (National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.), and DANIEL D. ELLEMAN (Jet Propulsion Lab., California Inst. of Tech., Pasadena) 1987 10 p Proposed for presentation at the 32nd International SAMPE Symposium and Exhibition, Anaheim, Calif., 6-9 Apr. 1987
(NASA-TM-88964; E-3420; NAS 1.15:88964) Avail: NTIS HC A02/MF A01 CSCL 22A

The opportunity to conduct microgravity and related research still exists, even with the temporary delay in the U.S. Space Shuttle program. Several ground-based facilities are available and use of these facilities is highly recommended for the preparation of near and far term shuttle or space station experiments. Drop tubes, drop towers, aircraft, sounding rockets and a wide variety of other ground-based equipment can be used to simulate microgravity. This paper concentrates on the materials processing capabilities available at NASA Lewis Research Center (NASA Lewis), Marshall Space Flight Center (MSFC), and the California Institute of Technology Jet Propulsion Laboratory (JPL). Also included is information on gaining access to these facilities. Author

N87-18597*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**EXPANDABLE PALLET FOR SPACE STATION INTERFACE ATTACHMENTS Patent Application**
CLARENCE J. WESSELSKI, inventor (to NASA) 13 Nov. 1986 18 p
(NASA-CASE-MSC-21117-1; NAS 1.71:MSC-21117-1; US-PATENT-APPL-SN-929875) Avail: NTIS HC A02/MF A01 CSCL 22B

The present invention is directed to a foldable expandable pallet having a basic square configuration. Each pallet is comprised of a plurality of struts joined together by node point fittings to make a rigid structure. The struts have hinge fittings which are spring loaded to permit collapse of the module for stowage transport to a space station in the payload bay of the space shuttle, and deployment on orbit. Dimensions of the pallet are selected to provide convenient, closely spaced attachment points between the node points of the relatively widely spaced trusses of a space station platform. A pallet is attached to a truss at four points: one close fitting hole; two oversize holes, and a slot which allows for thermal expansion/contraction and for manufacturing tolerances. Applications of the pallet include its use to attach rotary joints. Also, the pallet can serve as a splint with gridded plates; as instrument mounting bases; and as a roadbed for a Mobile Service Center (MSC). The novelty resides in providing closely spaced attachment points for mounting small components to the space station beams with widely spaced attachment points. The foldable expandable pallet removes the constraint that the main structure must have closely spaced node points for attachment purposes. Author

N87-18600*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**GROUND FACILITY FOR LARGE SPACE STRUCTURES DYNAMICS AND CONTROL VERIFICATION**
HENRY WAITES Nov. 1986 15 p
(NASA-TM-86558; NAS 1.15:86558) Avail: NTIS HC A02/MF A01 CSCL 22B

NASA Marshall Space Flight Center has developed a facility in which closed loop control of Large Space Structures (LSS) can be demonstrated and verified. The main objective of the facility is to verify LSS control system techniques so that on-orbit performance can be unsured. The facility consists of an LSS test article or payload which is connected to a 3-axis angular pointing mount assembly that provides control torque commands. The angular pointing mount assembly is attached to a base excitation system which will simulate disturbances most likely to occur for Orbiter and DOD payloads. The control computer contains the calibration software, the reference systems, the alignment procedures, the telemetry software, and the control algorithms. The total system is suspended in such a fashion that the LSS test article has the characteristics common to all LSS. Author

N87-20060*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
**WORKING GROUP 5: MEASUREMENTS TECHNOLOGY AND ACTIVE EXPERIMENTS**
E. WHIPPLE, J. N. BARFIELD, C.-G. FAELTHAMMAR, J. FEYNMAN, J. N. QUINN, W. ROBERTS, N. STONE, and W. L. TAYLOR *In its* Space Technology Plasma Issues in 2001 p 23-26 1 Oct. 1986
Avail: NTIS HC A20/MF A01 CSCL 20I

Technology issues identified by working groups 5 are listed. (1) New instruments are needed to upgrade the ability to measure plasma properties in space. (2) Facilities should be developed for conducting a broad range of plasma experiments in space. (3) The ability to predict plasma weather within magnetospheres should be improved and a capability to modify plasma weather developed. (4) Methods of control of plasma spacecraft and spacecraft plasma interference should be upgraded. (5) The space station laboratory facilities should be designed with attention to problems of flexibility to allow for future growth. These issues are discussed. Author

# 14

# GROWTH

Includes descriptions of scenarios, analyses and system technology requirements for the evolutionary growth of the Space Station system.

A87-15376
**SPACE STATION BEYOND IOC; PROCEEDINGS OF THE THIRTY-SECOND ANNUAL INTERNATIONAL CONFERENCE, LOS ANGELES, CA, NOVEMBER 6, 7, 1985**
M. J. FRIEDENTHAL, ED. (TRW, Inc., Federal Systems Div., Redondo Beach, CA) Conference sponsored by AAS. San Diego, CA, Univelt, Inc. , 1986, 187 p. For individual items see A87-15377 to A87-15390.

The progress in the design of the Space Station, mainly for the IOC, as of the end of 1985 is assessed, and plans for growth and applications of the Station are discussed. Emphasis is placed on the technologies which will require further development if the cost and timetable aspects of the Station are to be met. The tasks assigned in the individual Work Packages for the contracters and subcontracters are described, as are Station uses as a materials science, space physics, pharmaceuticals laboratory and astrometric observatory. M.S.K.

A87-15379
**SPACE STATION EVOLUTION - THE AEROSPACE TECHNOLOGY IMPACT**
W. E. STONEY (RCA, Astro-Electronics Div., Princeton, NJ) IN: Space Station beyond IOC; Proceedings of the Thirty-second Annual International Conference, Los Angeles, CA, November 6, 7, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 33-36.
(AAS PAPER 85-461)

Critical Space Station design goals which will require innovative solutions are discussed. Primary design objectives are flexibility for the user, an indefinite lifetime, and operational costs significantly lower than those of previous spacecraft. The equipment must satisfy the power, geometry, thermal, and communications needs of a variety of customers. All components must allow for change-out to accommodate repairs in-orbit. The concept will be extended to three modular levels of design, i.e., utility service, propulsion, payload and total functional system modules. M.S.K.

A87-15380
**SPACE STATION EVOLUTION - THE AEROSPACE TECHNOLOGY IMPACT**
R. W. HAGER (Boeing Aerospace Co., Seattle, WA) IN: Space Station beyond IOC; Proceedings of the Thirty-second Annual International Conference, Los Angeles, CA, November 6, 7, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 39-43.
(AAS PAPER 85-456)

Space Station-related technologies which will be further developed after IOC are described. The Station IOC may require 90-day resupply missions, each carrying 5000 lb of oxygen, nitrogen and water and picking up waste and delivering food for six astronauts. Logistics requirements will be reduced as the Station evolves into an ecological system within 3-5 percent of complete independence. One standard 43-ft module can hold enough growing plants to supply 2.5 astronauts and transform their wastes. Expert systems and low-cost, high power sources will be required for production-scale materials processing. M.S.K.

**A87-15381**
**SPACE STATION EVOLUTION - THE AEROSPACE TECHNOLOGY IMPACT (3)**
H. R. REICHERT (General Electric Co., Space Systems Div., Philadelphia, PA) IN: Space Station beyond IOC; Proceedings of the Thirty-second Annual International Conference, Los Angeles, CA, November 6, 7, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 57-63.
(AAS PAPER 85-460)

Work Package 3 of the Space Station Phase B design studies is described. Package 3 covers the free-flying polar and coplanar platforms, payloads attached to the Station, the Customer Service Facility and a general-purpose laboratory. The designs selected for the IOC are being developed to remain flexible and to satisfy user requirements. Part of the Phase B study is devoted to determining the level of automation and robotics which will meet operational and evolutionary objectives. M.S.K.

**A87-15386**
**EVOLUTIONARY TRANSPORTATION PATHS FOR PLANETARY MISSIONS**
J. C. NIEHOFF (Science Applications International Corp., Schaumburg, IL) IN: Space Station beyond IOC; Proceedings of the Thirty-second Annual International Conference, Los Angeles, CA, November 6, 7, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 105-110.
(AAS PAPER 85-476)

The advantages and impacts of using orbital staging platforms for planetary missions are discussed. The discussion is based on studies of launch scenarios for Mercury, Mars, and Ganymede orbiters; rendezvous with asteroids and a comet; and probes to Saturn, Titan, Uranus/Neptune, and Jupiter. An OTV such as the IUS or a Centaur G would be available at the Station for the interplanetary boost, but the orbit of the Station would be a detriment for some missions. M.S.K.

**A87-15839*#** National Aeronautics and Space Administration, Washington, D.C.
**APPLICATION OF ADVANCED TECHNOLOGY TO A PERMANENTLY MANNED SPACE STATION**
R. F. CARLISLE (NASA, Office of Space Station, Washington, DC) and M. NOLAN (NASA, Johnson Space Center, Houston, TX) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 12 p.
(IAF PAPER 86-60)

Advanced technologies developed by NASA's Space Station Advanced Development Program (ADP), which cover some 70 application areas, are discussed. Current data are presented that show promising applications in four of these areas: the Environmental Control and Life Support, Extravehicular Activities, Electrical Power, and Thermal Subsystem Design. I.S.

**A87-16019#**
**A 21ST CENTURY NUCLEAR POWER STRATEGY FOR MARS**
J. A. ANGELO, JR. (Florida Institute of Technology, Melbourne) and D. BUDEN (Science Applications International Corp., Albuquerque, NM) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 16 p. refs
(IAF PAPER 86-322)

Within the context of an emerging extraterrestrial civilization, the paper details the power requirements associated with the advanced exploration and eventual settlement of Mars. An account is given of the most recent Mars exploration and development scenarios and it is shown how the four basic nuclear energy source phenomena could play a leading role in the conquest of Mars in the next century. Radioactive decay and nuclear fission processes represent compact and self-sufficient power and propulsion technologies for detailed surface exploration, manned operations, base camp operations and the successful functioning of early settlements. Controlled thermonuclear fusion and/or the production and storage of useful quantities of antimatter represent energy technology breakthroughs that would revolutionize earth-to-Mars space transportation systems. K.K.

**A87-16096*#** National Aeronautics and Space Administration, Washington, D.C.
**TECHNOLOGIES FOR AFFORDABLE ACCESS TO SPACE**
R. S. COLLADAY and S. R. SADIN (NASA, Washington, DC) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p.
(IAF PAPER 86-442)

NASA plans for advanced research and technology programs aimed at reducing operating costs and extending the capability of future space systems are described. The evolution of an almost entirely space-based mode is discussed, including the role of earth launch, servicing, fabrication and assembly and communications. The development of technology for affordable access to space is examined, taking into account progress in the areas of telerobotics, machine autonomy, human autonomy, space-based manufacturing and construction, electric power, and space-based propulsion. C.D.

**A87-16110*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**SPACE STATION DESIGN FOR GROWTH**
E. B. PRITCHARD (NASA, Langley Research Center, Hampton, VA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p.
(IAF PAPER 86-461)

This paper reviews the current status of Space Station planning for growth as the basis of an assessment of potential Space Station evolution directions in the 21st Century to meet the challenges of the report of the U.S. National Commission on space, 'Pioneering the Space Frontier'. Thus future mission requirements are reviewed and assessed. Based on these requirements, evolution scenarios and potential configurations are developed. It is concluded that the Space Station, as a multipurpose facility, should evolve to a capability of 300 kW, crew of 18 and 5 lab modules. Beyond this capability it will be necessary to separate functions and establish two separate Space Stations, one for research and one for operational activities (e.g., transportation node, servicing, etc.). If the U.S. National Commission on space's recommendations are adopted, this separation or 'branching' could occur as early as 2005 to meet the needs of a permanent lunar base. Author

**A87-16931*#** National Aeronautics and Space Administration, Washington, D.C.
**FRONTIERS OF TECHNOLOGY**
R. CARLISLE (NASA, Office of Space Station, Washington, DC) and M. NOLAN (NASA, Johnson Space Center, Houston, TX) Aerospace America (ISSN 0740-722X), vol. 24, Sept. 1986, p. 48-51.

An evaluation is made of the Space Station technology assessment efforts conducted by NASA under its Advanced Development Program, which has over the last three years enlisted 14 different disciplines in the refinement of every aspect of Space Station interior and exterior design. Major investigations have delved into the application of novel coatings to materials subjected to prolonged exposure to radiation, the design of berthing and docking mechanisms, the demonstration of EVA structural assembly methods in a neutral buoyancy water tank, and an investigation of the effects of meteoroids and space debris on EVA garments, which have prompted the development of a novel 'hard' suit. O.C.

**A87-18064*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**SPACECRAFT 2000 - THE CHALLENGE OF THE FUTURE**
H. W. BRANDHORST, JR., K. A. FAYMON, and R. W. BERCAW (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1397-1400.

The need for spacecraft bus technology advances in order to develop the spacecraft for the 21st century is discussed.

Consideration is given to the power and electric propulsion systems for mass-limited satellites such as LEO and GEO. The goal of spacecraft bus technology programs is to design a cost-effective spacecraft which operates well in the satellite environment. The possibility of collaboration between government and industry is examined. I.F.

**A87-18127**
**ROBOTICS IN SPACE POWER SYSTEMS ASSEMBLY AND SERVICING**
G. R. LUTZ (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1768-1775.

Candidate on-orbit electrical power systems were evaluated to assess the level and type of robotic systems which could be advantageously implemented throughout the Space Station growth cycle. Robotics devices for the initial operating configuration of the Space Station are presented as well as future smart robots. Operating and performance characteristics of these devices are discussed and the use of teleoperators as an efficient means of augmenting crew activities is addressed. K.K.

**A87-18154*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**A FEASIBILITY ASSESSMENT OF NUCLEAR REACTOR POWER SYSTEM CONCEPTS FOR THE NASA GROWTH SPACE STATION**
H. S. BLOOMFIELD and J. A. HELLER (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1924-1932. refs

A preliminary feasibility assessment of the integration of reactor power system concepts with a projected growth Space Station architecture was conducted to address a variety of installation, operational, disposition and safety issues. A previous NASA sponsored study, which showed the advantages of Space Station - attached concepts, served as the basis for this study. A study methodology was defined and implemented to assess compatible combinations of reactor power installation concepts, disposal destinations, and propulsion methods. Three installation concepts that met a set of integration criteria were characterized from a configuration and operational viewpoint, with end-of-life disposal mass identified. Disposal destinations that met current aerospace nuclear safety criteria were identified and characterized from an operational and energy requirements viewpoint, with delta-V energy requirement as a key parameter. Chemical propulsion methods that met current and near-term application criteria were identified and payload mass and delta-V capabilities were characterized. These capabilities were matched against concept disposal mass and destination delta-V requirements to provide a feasibility of each combination. Author

**A87-21807*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**NASA GROWTH SPACE STATION MISSIONS AND CANDIDATE NUCLEAR/SOLAR POWER SYSTEMS**
JACK A. HELLER and JOSEPH J. NAINIGER (NASA, Lewis Research Center, Cleveland, OH) IN: Space nuclear power systems 1985; Proceedings of the Second Symposium, Albuquerque, NM, Jan. 14-16, 1985. Volume 3 . Malabar, FL, Orbit Book Co., Inc., 1987, p. 47-52. NASA sponsored research.

A brief summary is presented of a NASA study contract and in-house investigation on Growth Space Station missions and appropriate nuclear and solar space electric power systems. By the year 2000 some 300 kWe will be needed for missions and housekeeping power for a 12 to 18 person Station crew. Several Space Station configurations employing nuclear reactor power systems are discussed, including shielding requirements and power transmission schemes. Advantages of reactor power include a greatly simplified Station orientation procedure, greatly reduced occultation of views of the earth and deep space, near elimination of energy storage requirements, and significantly reduced station-keeping propellant mass due to very low drag of the reactor power system. The in-house studies of viable alternative Growth Space Station power systems showed that at 300 kWe a rigid silicon solar cell array with NiCd batteries had the highest specific mass at 275 kg/kWe, with solar Stirling the lowest at 40 kg/kWe. However, when 10 year propellant mass requirements are factored in, the 300 kWe nuclear Stirling exhibits the lowest total mass. Author

**A87-28953**
**EXTENDING THE SPACE STATION INFRASTRUCTURE**
C. M. HEMPSELL (British Aerospace, PLC, Space and Communications Div., Stevenage, England) British Interplanetary Society, Journal (Space Stations) (ISSN 0007-084X), vol. 40, Jan. 1987, p. 19-26.

The Space Station program will create an infrastructure of support elements in the space environment. This program has widespread international collaboration producing many different elements, but despite this there remains a potential for expansion of the infrastructure in terms of new locations and the facilities offered. This paper lists 71 possible major systems of which only 21 are currently projected for development. The constraints on further expansion being funding limitations. To allow expansion of the Station beyond the initial operational configuration the paper proposes three approaches: (1) review funding sources, (2) design elements to allow expansion, and (3) introduce multifunction designs. Author

# 15

# EXPERIMENTS, TETHERS, AND PLATFORMS

Includes descriptions and requirements of experiments and tethers onboard the Space Station and platforms that are either co-orbiting with the Space Station, in polar orbit, or in geosynchronous orbit and which are part of the Space Station system.

**A87-10045**
**CUSTOMER UTILIZATION REQUIREMENTS AND THEIR IMPACT FOR SPACE STATION CAPABILITIES**
M. E. VAUCHER (Center for Space Policy, Inc., Cambridge, MA) IN: Space Congress, 23rd, Cocoa Beach, FL, April 22-25, 1986, Proceedings . Cape Canaveral, FL, Canaveral Council of Technical Societies, 1986, p. 7-12 to 7-74.

The effect of customer requirements on the design of Space Station capabilities is evaluated. Market and environment analyses were utilized to determine the potential Space Station users and their requirements. The Station users are identified as commercial, NASA, academic and scientific, international, and NOAA and they are grouped functionally. In order to determine users needs, the functional capabilities of the Station's systems are related to the users requirements. Attribute matrix scores were applied to the core capabilities and user specific attributes of the Station, and four functional grouping were identified: (1) manned microgravity, (2) research on-orbit service and assembly, (3) on-orbit observations/remote sensing, and (4) commercial materials manufacturing. It is noted that the three main design goals for the Station are: (1) design to cost, (2) design for growth, and (3) user friendly. I.F.

**A87-10046*** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

**SPACE STATION MICROGRAVITY AND MATERIALS PROCESSING FACILITY A NATIONAL LABORATORY DEDICATED TO U.S. INTERESTS**

H. L. ATKINS (NASA, Marshall Space Flight Center, Huntsville, AL), E. R. PEVEY, and T. MOOKHERJI (Teledyne Brown Engineering, Huntsville, AL) IN: Space Congress, 23rd, Cocoa Beach, FL, April 22-25, 1986, Proceedings . Cape Canaveral, FL, Canaveral Council of Technical Societies, 1986, p. 7-75 to 7-89. (Contract NAS8-36122)

The Microgravity and Materials Processing Facility (MMPF) of the Space Station is examined. The MMPF is designed to accomodate individual experiments and associated hardware and is to be housed in the Manufacturing and Technology Laboratory Module. The objectives of the microgravity and materials processing study and the user, experiment/equipment, MMPF system requirements, and programmatics and planning development tasks of the study are described. Consideration is given to the acceleration environment, on-orbit sample preparation and analysis, mission-time-line analyses, and payload complement trades. Diagrams of the MMPF are presented. I.F.

**A87-10546**

**A SPACE PLATFORM WITH CO-ORBITING RELAY SATELLITES**

T. J. SHESKIN (Cleveland State University, OH) British Interplanetary Society, Journal (Space Technology) (ISSN 0007-084X), vol. 39, Aug. 1986, p. 357-361. refs

A primary goal of the U.S. Space Station (SS) is the development of advanced automation techniques. One primary manifestation of this goal may be teleoperators being controlled by groundside experimenters. However, the SS will not always be in direct radio contact with a given earth station, and a radio link through the TDRSS satellites would introduce delays exceeding 0.3 sec in response time, an unacceptable duration. Therefore, a space platform is proposed for the experimentation, and would be linked with the ground by 16 co-orbiting relay satellites in 400 km orbits. The propagation delays would then be limited to 0.142 sec for an earth station at the equator. Numerical models are reviewed for choosing appropriate spacing for the satellites, for direct linking with the platform, and for optimizing the distance between the platform and the SS. Millimeter-wave and laser links are discussed as candidate communications links. M.S.K.

**A87-10547**

**MATERIALS RESEARCH IN SPACE - EXPERIMENTAL TOOL OR PRODUCTION BASE?**

B. DERBY (Oxford University, England) British Interplanetary Society, Journal (Space Technology) (ISSN 0007-084X), vol. 39, Aug. 1986, p. 362-365. refs

Due to the relatively high gravity field and vibrations that will be experienced on the Space Station (SS), a platform serviced from the SS and nominally in a higher orbit will probably be used for space-based materials processing. However, orbits high enough to provide gravity of about 1/10 millionth g cause second-order effects such as Marangoni convection, segregation, repulsion of particles by an advancing solid interface, etc., which have been observed in Spacelab to dominate. Crystal growth is a particularly appealing candidate for space materials production. Also, perfect spheres, useful as standards on earth, may be manufactured in space because liquids in microgravity tend to their lowest energy configuration, i.e., spheres. Finally, electrophoresis-produced pharmaceuticals and single crystals which are unstable at high temperatures may also be grown in space. The main characteristic of the first commercial products will be a high value per mass. M.S.K.

**A87-10548**

**THE UTILISATION OF THE SPACE STATION FOR GAMMA-RAY ASTRONOMY**

J. N. CARTER, M. J. COE, A. J. DEAN, and D. RAMSDEN (Southampton, University, England) (British Interplanetary Society, Space Station Applications Symposium, London, England, Sept. 25, 1985) British Interplanetary Society, Journal (Space Technology) (ISSN 0007-084X), vol. 39, Aug. 1986, p. 366-371. refs

The status of gamma ray astronomy (GRA) is assessed and the GRA activities that will probably be a part of the Space Station (SS) are projected. Present GRA efforts use gamma ray data collected on the earth and by satellites such as the Einstein Observatory and COS-B to characterize explosive nuclear events occurring in the sun, pulsars, the galaxy, active galactic nuclei and extended galactic objects such as supernovae. Coded aperture masks over a position-sensitive plane and time coded modulation techniques now permit accurate mappings of celestial gamma ray sources. GRA instruments operated in conjunction with the SS will be mounted on a separate, co-orbiting platform serviced from the SS. Angular resolution of 0.001 arcsec will be possible. The availability of humans in space will allow experimentation with new types of instrumentation and combinations of instruments. Finally, a modular GRA telescope is described which can be increased in power and resolution as budgets allow. M.S.K.

**A87-11000*** Arizona Univ., Tucson.

**OPTICIANS AS ASTRONAUTS**

J. R. P. ANGEL (Steward Observatory, Tucson, AZ) IN: Large optics technology; Proceedings of the Meeting, San Diego, CA, August 19-21, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 40, 41. refs (Contract NAGW-121)

One of the most useful tasks to be carried out at the Space Station will be the making of large precision telescopes. It will become possible to assemble optics bigger than can be launched in one piece. A further step would be to take advantage of extraordinarily favorable conditions in space for testing and even manufacturing optics. In this short paper, these two aspects are considered. Author

**A87-11003**

**APPLICATION OF REPLICATED GLASS MIRRORS TO LARGE SEGMENTED OPTICAL SYSTEMS**

M. H. KRIM (Perkin-Elmer Corp., Space Science Div., Danbury, CT) IN: Large optics technology; Proceedings of the Meeting, San Diego, CA, August 19-21, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 60-75.

Attention is given to the approach by which large, high specular reflectance, lightweight mirrors able to withstand thousands of deep heating and cooling cycles without degradation (for unlimited orbital operation) can be designed. An account is given to the principal sources of optics degradation, together with the effect of cumulative LCCs of different candidate materials. The potential advantages of glass are noted. Concentrator segment design and fabrication concepts are presented, with a view to their possible application to such other projects as long wavelength IR imaging systems. O.C.

**A87-11008**

**ITEK OPTICAL TECHNOLOGY IN MANUFACTURING AND METROLOGY**

I. M. EGDALL and R. K. LEE (Litton Industries, Inc., Itek Optical Systems Div., Lexington, MA) IN: Large optics technology; Proceedings of the Meeting, San Diego, CA, August 19-21, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 115-122. refs

There is a wide spectrum of optical systems contemplated for use in future astronomy missions. At Itek, the systems range from the large, lightweight, deployable optics required for the Large Deployable Reflector (LDR) to the precision of grazing incidence X-ray optics for the Advanced X-ray Astrophysical Facility (AXAF). This paper describes some of the technological initiatives that

Itek has developed to enhance the manufacturability and the measurement of the surface quality of the spectrum of optical assemblies to be manufactured for the astronomical telescopes.
Author

**A87-13716*** Virginia Univ., Charlottesville.
**VISUAL MONITORING OF AUTONOMOUS LIFE SCIENCES EXPERIMENTATION**
G. E. BLANK and W. N. MARTIN (Virginia, University, Charlottesville) IN: Space station automation; Proceedings of the Meeting, Cambridge, MA, September 17, 18, 1985. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1985, p. 88-94. refs
(Contract NAG5-597; NSF ECS-83-07248)

The goal of this research project is the development of a computer vision system to monitor and control life sciences experimentation on board space stations. The vision system is organized as a multiprocessor system with distributed processes selectively analyzing hierarchical imagery in order to monitor and control the appropriate instrumentation.
Author

**A87-13950**
**MATERIALS PROCESSING**
D. DOOLING (Essex Corp., Huntsville, AL) Commercial Space (ISSN 8756-4831), vol. 2, Summer 1986, p. 66-71.

Current undertakings of NASA's Marshall Space Flight Center are described. Particular attentin is given to the Microgravity Materials Processing Facility (MMPF) which will use the US lab module and external facilities on the US/international space station in material science experiments. Two categories of equipment have been identified for the MMPF: support, to help perform experiments, and characterization, to understand the results. The feasibility of developing a superconducting magnet to suppress residual convection currents and a superhard vacuum wake shield for use in special deposition processes is assessed.
K.K.

**A87-14051#**
**NONLINEAR CONTROL LAWS FOR TETHERED SATELLITES**
A. BOSCHITSCH and O. O. BENDIKSEN (Princeton University, NJ) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 21 p. refs

Optimal control theory is used to find retrieval rate histories that reduce in-plane and out-of-plane librational motions of a tethered satellite. This is carried out by minimizing a cost function that penalizes these motions. A first order conjugate gradient method is implemented in obtaining the optimal control, and corresponding trajectories for different weightings in the cost function are presented. By suitable choice of these weightings the librational motion can be significantly reduced. It is found that in-plane oscillations are more readily attenuated than out-of-plane oscillations. Tension levels remain within acceptable limits but become smaller for shorter tether lengths. Criteria for selecting appropriate weightings are not readily defined and further examination of the cost function structure is recommended.
Author

**A87-14052#**
**DYNAMICAL EFFECTS OF TETHER STRUCTURAL DAMPING - A PRELIMINARY MODEL**
S. BEGAMASCHI (Padova, Universita, Padua, Italy), A. SINOPOLI (Venezia, Universita, Venice, Italy), and W. LAZZARIN NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 12 p. refs
(Contract CNR-PSN-85,037)

A model in which the tether is simulated as a continuum subjected to viscoelastic damping is developed. The dynamical equation for the small-amplitude free longitudinal vibrations of a tether subjected to internal damping and the boundary conditions are presented and solved. Graphs of the first five nondimensionalized frequencies for two different tether lengths and the periods of the same undamped modes are provided.
I.F.

**A87-14054#**
**THE BEHAVIOR OF LONG TETHERS IN SPACE**
D. A. ARNOLD (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 17 p.

The behavior of satellites connected by long tethers is discussed in terms of basic physical principles with some mathematics included. The topics included the gravitational, centrifugal, and aerodynamic forces on the system, vertical stabilization using the gravity gradient force, librations of the system, and longitudinal and transverse motions of the tether. Deployment and retrieval of the system are discussed, along with strategies for controlling librations particularly during retrieval. Other topics include the use of tethers for exchanging energy and momentum between satellites, tether strength requirements and tapering techniques in long or rotating systems, and instability of a particular type of extremely long tethered configuration.
Author

**A87-14055#**
**A SYSTEMS STUDY OF A 100 KW ELECTRODYNAMIC TETHER**
M. MARTINEZ-SANCHEZ and D. E. HASTINGS (MIT, Cambridge, MA) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 27 p. refs

The design of useful electrodynamic power and propulsive tether systems for powers up to 100 kW, and the comparative performance and cost of the most important aplications of such systems are reviewed. Drag compensation and orbit altitude changes are the main propulsive missions identified; power generation in a stand-alone mode, with rocket force make-up is shown to offer large fuel savings when compared to fuel cells, but the system mass and complexity are increased due to large magnetic field and electron density fluctuations over one orbit.
Author

**A87-14057*#** Martin Marietta Corp., Denver, Colo.
**DESIGN AND FABRICATION OF THE 20 KM/10 KV ELECTROMECHANICAL TETHER FOR TSS-1 USING HIGH IMPACT CONDUCTOR (HIWIRE)**
E. SCALA, D. P. BENTLEY (Cortland Cable Co., Inc., NY), and L. S. MARSHALL (Martin Marietta Corp., Denver, CO) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 8 p.
(Contract NAS8-36000)

The development of a 20-km electromechanical tether for the tethered satellite system (TSS) is described. The basic design requirements for electromagnetic cables and for conductors in cables subject to stresses and cyclic loading are discussed. The tether fabricatioon procedures involve: (1) conductor twisting around the core, (2) insulation extrusion, (3) strength member braiding, and (4) protective jacket braiding.
I.F.

**A87-14058#**
**TETHERED PLATFORMS - NEW FACILITIES FOR SCIENTIFIC AND APPLIED RESEARCH IN SPACE**
F. BEVILACQUA, P. MERLINA, and A. ANSELMI (Aeritalia S.p.A., Gruppo Sistemi Spaziali ed Energie Alternative, Turin, Italy) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 18 p. refs

Issues related to the use of tethered platforms to support Space Station operations and experiments are considered. The platform is analyzed in terms of flexibility, serviceability, compatibility, and orbit, and the lifetime of the tether is evaluated based on tether diameter and length. The requirements and operation of the Space Elevator designed for transport of materials between the platform and Space Station are described.
I.F.

**A87-14059#**

**FAST (3/4 ORBIT) DEPLOYMENT OF A TETHERED SATELLITE PAIR TO THE LOCAL VERTICAL**

A. H. VON FLOTOW and P. R. WILLIAMSON (Stanford University, CA) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 23 p. refs

This paper presents a new family of deployment trajectories for a pair of tethered satellites. Deployment begins in orbit with the two satellites in physical contact, and progresses to the final state with the tethered pair stabilized along the local vertical. The entire deployment is accomplished in less than one orbit, using only gravity gradient to generate the required angular rate of the deployed system. These fast deployment trajectories are achievable with very crude deployment hardware. The paper presents simulations of the autonomous deployment of an existing sounding rocket plasma diagnostics payload, using only a single cold gas attitude control system for each sub-satellite. No complex tether controller is required. Tether deployment velocity is commanded and maintained against friction by thruster firing. Author

**A87-14060*#** National Aeronautics and Space Administration, Washington, D.C.

**HISTORICAL EVOLUTION OF TETHERS IN SPACE**

I. BEKEY (NASA, Office of Space Flight, Washington, DC) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 5 p.

The evolution of concepts of the application of tethers in space is traced from its origin in the last century to today's tethered satellite system project. Early, ambitious concept descriptions are followed by sporadic efforts in late 1960's to the 1970's until NASA entered into systematic investigations of the theoretical and practical feasibility of various applications. These efforts culminated in the establishment of the Tethered Satellite System Project presently under development at NASA and Aeritalia. Author

**A87-14061*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.

**TETHER IMPLICATIONS ON SPACE STATION GRAVITY LEVEL**

K. R. KROLL (NASA, Johnson Space Center, Houston, TX) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 13 p. refs

The use of a tether on the Space Station is discussed. The effefcts of the tether on the microgravity environment on the Space station are described. A tethered variable gravity laboratory for investigating low gravity processes using gravity magnitude and time as variables is considered. I.F.

**A87-14062*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**ATTITUDE CONTROL OF TETHERED SPACECRAFT**

L. G. LEMKE (NASA, Ames Research Center, Moffett Field, CA), J. D. POWELL, and X. HE (Stanford University, CA) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 17 p.

Procedures for achieving attitude control of single-body and multibody, tethered spacecraft are examined. The design considerations for attitude control and the generation of control torques are described. Two dimensional tether attach point motion is utilized to produce torque about two axes and the third axis is controlled with either a control moment gyro or a reaction wheel. The ability to perform attitude control of a tethered spacecraft is evaluated in the Kinetic Isolation Tether Experiment (KITE). It is observed that the KITE/SPARTAN design bandwidth is adequate to fully utilize the capability of attitude sensors with accuracies in the 1-arcsec range. I.F.

**A87-14064*#** Alabama Univ., Huntsville.

**FEASIBILITY ASSESSMENT OF THE GET-AWAY TETHER EXPERIMENT**

M. GREENE (Alabama, University, Huntsville), C. C. RUPP (NASA, Marshall Space Flight Center, Huntsville, AL), and A. LORENZONI (CNR, Rome, Italy) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 15 p. refs

The small free-flying tether system deployable from a Get-Away Special canister is analyzed. The objectives of the GAS experiment which include demonstrating electric power generation and orbital reboost using electrodynamic technology, measuring micrometeoroid hazards to the tethers, conducting a radio propagation experiment, and measuring long wire radar-cross-section are discussed. The physical layout and components of the mother and daughter satellites are described. The command and control system of the tether system is examined. The electrodynamic experiments to be conducted after plasma contact is established and the electrodynamical capabilities of the system are considered. I.F.

**A87-14065#**

**TETHERED ELEVATOR AND POINTING PLATFORM DEMONSTRATIONS - A SHUTTLE FLIGHT TEST OF SCALED ENGINEERING MODELS**

P. MERLINA, W. BOGO, and S. CIARDO (Aeritalia S.p.A., Gruppo Sistemi Spaziali ed Energie Alternative, Turin, Italy) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 26 p.

The proposed in-flight demonstrations of the capabilities of a Space Elevator and a Pointing Platform are examined. The use of a Space Elevator for microgravity and transportation applications is discussed. The effects of perturbating acceleration propagating along the tether on the microgravity environment and of dynamics disturbances on the transfer of motion are to be investigated in the Space Elevator in-flight test. The planned configuration and drive mechanism for the Space Elevator are described. The objectives of the Pointing Platform demonstration, and the measurement and control system and the actuator of the Pointing Platform are considered. I.F.

**A87-14066#**

**DEVELOPMENT, TESTING, AND EVALUATION OF NEW TETHER MATERIALS**

R. F. ORBAN (Material Concepts, Inc., Columbus, OH) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 13 p.

New approaches to conductive tether construction replace solid copper wire with multifilament tows of as many as 2000 microstrands of Kevlar impregnated with metal. Metals include copper for its conductivity (it may be overcoated with nickel for abrasion and oxidation resistance) and numerous other combinations of metals and synthetics. Space applications introduce new environmental dangers such as atomic oxygen, outgassing under vacuum, and extreme temperature variation. Extremely flexible tethers can be designed to withstand any predictable condition of use and environment. However, before application for any specific use, the tethers must be characterized fully as the physical parameters to be required of them. Work underway to attain this comprehensive characterization is described. Author

**A87-14067#**

**DISTURBANCE PROPAGATION IN ORBITING TETHERS**

F. GRAZIANI, S. SGUBINI, and A. AGNENI (Roma I, Universita, Rome, Italy) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 16 p. refs

This paper deals with the analysis of the tip mass effects on the dynamic behavior of a tether clamped at a station in a circular orbit. The dynamic response is obtained in a closed form even if a tip mass is present. A filtering behavior for the out-of plane

motion has been pointed out with the cut-off frequency equal to the orbit mean motion. Author

**A87-14068#**
**PUMPING A TETHERED CONFIGURATION TO BOOST ITS ORBIT AROUND AN OBLATE PLANET**
J. V. BREAKWELL (Stanford University, CA) and J. W. GEARHART (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 23 p.

A tethered satellite in a circular near-polar orbit is pitching forward, relative to the local vertical, at an average rate equal to the orbital rate. The pitching is phased so that the tether is vertical 1/8th of an orbit prior to an equatorial crossing and horizontal 1/8th of an orbit after a crossing. Pumping of the tether is necessary to maintain this phase, and the resulting increase in energy raises the orbit. A formula is obtained for the rate of increase of altitude. Author

**A87-14069#**
**A SURVEY ON THE DYNAMICS AND CONTROL OF TETHERED SATELLITE SYSTEMS**
A. K. MISRA (McGill University, Montreal, Canada) and V. J. MODI (British Columbia, University, Vancouver, Canada) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 54 p. refs

The vast potential of tethered satellite systems has led to many investigations of their dynamics and control during deployment, stationkeeping, and retrieval phases. This paper reviews these analyses. To start with, the studies involving the pre-Shuttle era cable connected systems are cited briefly. The paper considers the Shuttle-borne tethered systems in depth. Dynamics and control results available in the literature are presented. Various deployment and retrieval schemes are considered. Unlike deployment, retrieval of tethered systems is basically unstable, making it necesary to use a control system to arrest the growth of rotational and vibrational motions. Control laws used by various investigators are discussed. Also considered are the dynamical studies associated with tethered platforms, tethered constellations, and orbital transfer using a tether. These are relatively fewer, and it is recommended to conduct further studies in this potentially important area. Finally, it is observed that there is an important need for experimental validation. Flight verification of the existing dynamical models and control schemes is strongly recommended. Author

**A87-14070#**
**POWER GENERATION WITH ELECTRODYNAMIC TETHERS**
M. VIGNOLI, W. MILLER, and M. MATTEONI (Aeritalia S.p.A., Gruppo Sistemi Spaziali ed Energie Alternative, Turin, Italy) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 11 p.

Earth-orbiting tether systems are capable of converting mechanical energy into electrical energy by utilizing the interaction between a conductive tether and the geomagnetic field, at the expense of orbital energy. The high differential voltage thus generated between two tether ends can be used to produce usable electrical energy through a suitable coupling of the tether ends with the space plasma, especially with the use of 'plasma contacting' devices. Author

**A87-14071#**
**PRELIMINARY ANALYSIS OF A SAR INTERFEROMETER USING A TETHERED SYSTEM**
A. MOCCIA and S. VETRELLA (Napoli, Universita, Naples, Italy) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 12 p. CNR-supported research. refs

A tethered SAR interferometer in which two vertically spaced physical antennas are carried along parallel paths by the deployer and the tethered subsatellite is analyzed. The interferometric technique is described in terms of the distance between antennas. The planimetric and altimetric accuracies atainable by deploying the tethered antenna downward are examined. A Space Shuttle mission to collect high resolution terrain images with the tethered SAR interferometer is proposed. I.F.

**A87-14072#**
**SELF-POWERED, DRAG-COMPENSATED, TETHERED SATELLITE SYSTEM AS AN ORBITING TRANSMITTER AT ULF/ELF**
R. D. ESTES and M. D. GROSSI (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 14 p. refs

The development of a self-powered, drag-compensated, tethered satellite system which performs as an orbiting transmitter at ULF/ELF is described. A method for obtaining a long orbital life for the system and self-powered operation of the tether is discussed. The electrodynamic drag compensation and signal generation are achieved by operating the system in two modes, generator of dc electric power and thruster. I.F.

**A87-14073*#** Ball Aerospace Systems Div., Boulder, Colo.
**GRAVITY GRADIENT ENHANCEMENT DURING TETHERED PAYLOAD RETRIEVAL**
R. E. GLICKMAN and S. C. RYBAK (Ball Corp., Ball Aerospace Systems Div., Boulder, CO) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 22 p. NASA-supported research. refs

Kane's (1984) Crawler System for satellite retrieval is enhanced by incorporating out-of-plane as well as in-plane motion. It is shown that a fixed length deployed tether applies stabilizing restoring forces to the payload during retrieval phase, and in effect, significantly reduces both the in-plane equilibrium hangoff angles and the build-up of in-plane and out-of-plane swinging. These Crawler System characteristics suggest that a simpler control system can be utilized and that significantly faster deployment and retrieval scenarios are possible without compromising safety. K.K.

**A87-14074*#** Howard Univ., Washington, D. C.
**THE DYNAMICS AND CONTROL OF A SPACE PLATFORM CONNECTED TO A TETHERED SUBSATELLITE**
R. FAN (Howard University, Washington, DC; Beijing Institute of Control Engineering, People's Republic of China) and P. M. BAINUM (Howard University, Washington, DC) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 19 p. Research supported by the Ministry of Astronautics of the People's Republic of China, Howard University, and NASA. refs

A mathematical model of the open and closed loop dynamics of a space tethered-platform-subsatellite system (TPS) is developed. The TPS consists of a rigid platform from which an (assumed massless) tether is deploying a subsatellite from an attachment point which is offset from the mass center of the platform. Control is provided by modulation of the tension level in the tether and by momentum-type platform-mounted devices. Control-law gains are obtained based on linear quadratic regulator techniques. Typical transient responses are presented. Author

**A87-14075#**
**J2 PERTURBATIONS ON THE MOTION OF TETHERED PLATFORMS**
S. BERGAMASCHI (Padova, Universita, Padua, Italy) and C. SAVAGLIO NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 11 p. refs
(Contract CNR-PSN-85,037)

The purpose of this work is to investigate the perturbations of the earth oblateness on the librations of tethered platforms in LEO. Dynamical equations are derived taking into account J2 effects and numerical results relative to different orbits are presented. It is concluded that forced motions around the local vertical are small, but would be significant if precise pointing is to be required in future applications. Author

**A87-14076#**
**JAPANESE CONCEPTS OF TETHER APPLICATION**
S. SASAKI, K.-I. OYAMA, and M. NAGATOMO (Tokyo, University, Japan) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 7 p.

Three experiments concerned with tether applications in Japan are described. The microwave energy transmission experiment utilizes a microwave transmitter onboard a platform and a microwave receiver tethered to evaluate the applicability of microwave energy transmission technology to power supply, power transmission, and the study of the interaction of microwave energy beams with the ionosphere and the atmosphere. The active electrodynamic tether experiment combined with electron beam emission is designed to be conducted on a free-flying platform and to examine the responses of ionospheric plasma to large potential differences. The use of a large Japanese satellite combined with a minimum of four subsatellites to simultaneously collect geophysical data at different altitudes in the lower ionosphere is discussed. I.F.

**A87-14077*#** Tokyo Univ. (Japan).
**RESULTS FROM A SERIES OF US/JAPAN TETHERED ROCKET EXPERIMENTS**
S. SASAKI, K.-I. OYAMA, N. KAWASHIMA, T. OBAYASHI (Tokyo, University, Japan), K. HIRAO (Tokai University, Kanagawa, Japan) et al. NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 12 p. refs
(Contract NAGW-235)

Tethered rocket experiments have been carried out four times during a US-Japan joint space program in progress since 1980. The goal of the rocket program has been to perform a new type of active experiment by ejecting an electron beam from the tethered mother-daughter payload system. In the third and fourth rocket flights, the conductive tether wire was deployed more than 400 m. It was found that the tether wire acted as an antenna and its antenna impedance decreased with the extension of the wire both in HF and VLF bands. The vehicle charging due to the beam emission up to 80 mA was repeatedly measured in the series of the experiments. During the 80 mA emission, a clear evidence for the ignition of a beam plasma discharge was obtained by the plasma probe, photometers and wave receivers. Author

**A87-14078#**
**TETHERED SATELLITE SYSTEM CAPABILITIES**
T. D. MEGNA (Martin Marietta Corp., Denver, CO) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 14 p.

The capabilities of the tethered satellite system (TSS) are examined. The TSS consists of a deployer mounted on a Spacelab enhanced multiplexer-demultiplexer pallet, science equipment mounted on a mission peculiar equipment support structure located in the orbiter cargo bay, and a satellite attached to the deployer by a tether. The designs and functions of the satellite, deployer, and tether are described. I.F.

**A87-14079#**
**NEW APPLICATIONS OF TETHERED SATELLITES - AN ITALIAN PERSPECTIVE**
E. VALLERANI and F. BEVILACQUA (Aeritalia S.p.A., Gruppo Sistemi Spaziali ed Energie Alternative, Turin, Italy) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 9 p.

The advantages and uses of permanent tethered platforms are discussed. The platforms are applicable to materials science, life science, space science, and technology in space experiments. The capabilities of the science and applications tethered platform, tethered elevator facility, electrodynamic tether power thrust generator system, and tethered elevator-based reentry probe are described. I.F.

**A87-14080#**
**CRITICAL SPACE TECHNOLOGY NEEDS FOR TETHER APPLICATIONS**
W. A. BARACAT and C. F. GARTRELL (General Research Corp., McLean, VA) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 22 p. refs

This paper presents an independent investigation into critical space technology needs for proposed future tether applications as described in the Tethers in Space Handbook being prepared for the National Aeronautics and Space Administration. An in-depth comparison is made of concept technology needs and expected technology capabilities derived from ongoing U.S. research and technology programs. The paper identifies critical space system technologies which require additional research or advancement to enable the tether application missions. These critical technologies are concentrated in the discipline areas of space materials, environmental interactions, controls and power. Author

**A87-14081*#** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
**SCIENTIFIC PURPOSES OF EARTH ORBITAL TETHER OPERATIONS**
W. J. WEBSTER, JR. (NASA, Goddard Space Flight Center, Greenbelt, MD) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 12 p. refs

The earth orbiting tethered systems will allow long-term observations of the 90-130 km environment and spatial gradiometry at altitudes from 130-400 km. The advantages such tethered systems could provide to the physics of the atmosphere/magnetosphere boundary, and the spatial and temporal structure of the earth's gravity and magnetic fields are discussed. The physical characteristics of the polar and equatorial regions, and the ionosphere and upper atmosphere are described. I.F.

**A87-14082*#** Martin Marietta Corp., Denver, Colo.
**ELECTRODYNAMIC TETHERS FOR ENERGY CONVERSION**
W. NOBLES (Martin Marietta Corp., Denver, CO) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 20 p.
(Contract NAS8-35499)

Conductive tethers have been proposed as a new method for converting orbital mechanical energy into electrical power for use on-board a satellite (generator mode) or conversely (motor mode) as a method of providing electric propulsion using electrical energy from the satellite. The operating characteristics of such systems are functionally dependent on orbit altitude and inclination. Effects of these relationships are examined to determine acceptable regions of application. To identify system design considerations, a specific set of system performance goals and requirements are selected. The case selected is for a 25 kW auxiliary power system for use on Space Station. Appropriate system design considerations are developed, and the resulting system is described. Author

**A87-14083*#** Martin Marietta Corp., Denver, Colo.
**BENEFITS OF TETHER MOMENTUM TRANSFER TO SPACE STATION OPERATIONS**
W. R. WOODIS and J. M. VANPELT (Martin Marietta Corp., Denver, CO) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 20 p. NASA-supported research. refs

A full solar cycle (1994-2004) is analyzed to study tether and nontether Space Station operations. The Space Station yearly altitude variation for the two approaches are investigated; it is observed that the optimum tether approach provides greater benefits that the nontether approach due to the cargon weight gain associated with the preferred low altitudes of the optimum variable altitude tether approach. The advantages provided by the combining a variable altitude/OTV launch approach are discussed. The baseline and tethered Shuttle deployments are compared and

the design and capabilities of the deployer system are examined. I.F.

**A87-15383*** Arizona Univ., Tucson.
**A SPACE STATION-BASED SEARCH FOR OTHER PLANETARY SYSTEMS**
E. H. LEVY (Arizona, University, Tucson) IN: Space Station beyond IOC; Proceedings of the Thirty-second Annual International Conference, Los Angeles, CA, November 6, 7, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 83-89. NASA-supported research.
(AAS PAPER 85-466)
The physical forces shaping and maintaining the form of the solar system and disk galaxies are reviewed to define the basis for an observational campaign from the Space Station, to find other planetary systems. The evolution of the distribution of types of matter in the solar system is regarded as typical of the formation of planetary systems around other stars. The observation campaign would cover 100 stars out to 10 pc and last 15-30 yr. Technological challenges which must be met to realize the telescope on the Station are described. M.S.K.

**A87-15388*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**PLANETARY DETECTION AND THE ASTROMETRIC TELESCOPE FACILITY - A SPACE STATION ATTACHED PAYLOAD**
B. L. SWENSON (NASA, Ames Research Center, Moffett Field, CA) IN: Space Station beyond IOC; Proceedings of the Thirty-second Annual International Conference, Los Angeles, CA, November 6, 7, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 117-124. refs
(AAS PAPER 85-478)
Astrometric measurements with 1-microarcsec accuracy from the Space Station could reveal terrestrial-sized planets orbiting stars within 10 pc of earth. Interferometry from the Station could furnish the needed acuity, while direct imaging could not. A proposed Astrometric Telescope Facility would be attached to the Station on an equatorial mount and would have a 15-m focal length. M.S.K.

**A87-15408*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**RELIABILITY AND MAINTENANCE SIMULATION OF THE HUBBLE SPACE TELESCOPE**
F. PIZZANO (NASA, Marshall Space Flight Center, Huntsville, AL) IN: 1986 Annual Reliability and Maintainability Symposium, Las Vegas, NV, January 28-30, 1986, Proceedings . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, p. 83-87.
An analytical approach is presented which was developed and implemented at MSFC specifically for the Space Telescope Program to provide comparisons of critical item failures, system downstates, on-orbit servicing versus return for ground maintenance, overall system downtime, and to obtain a measure of expected uptime for science functions. Author

**A87-15536**
**INVESTIGATION OF THE RELATIVE MOTION OF TWO TETHERED BODIES WITH REGULATED TETHER LENGTH [ISSLEDOVANIE OTNOSITEL'NOGO DVIZHENIIA SVIAZKI DVUKH TEL PRI REGULIRUEMOI DLINE TROSA]**
V. A. IVANOV and D. A. LAPTYREV Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 24, July-Aug. 1986, p. 544-552. In Russian. refs
The qualitative theory of dynamic systems is used to study all possible types of trajectories of the relative motion of two tethered satellites for two sufficiently general laws for the regulation of tether length. Mathematical modeling is used to assess the applicability of the qualitative results to the analysis of the relative motion of the tethered bodies with allowance for the effect of a number of perturbing factors. Simulation results are presented for spacecraft motion in an elliptical orbit. B.J.

**A87-15748#**
**FEASIBILITY STUDY FOR THE DEVELOPMENT OF A FREE-FLYING PAYLOAD CARRIER TO SUPPORT THE CANADIAN SPACE SCIENCE PROGRAM**
R. D. HENDRY (National Research Council of Canada, Ottawa), B. R. PAYNE, and K. WALSH (Bristol Aerospace, Ltd., Winnipeg, Canada) AIAA, Conference on Sounding Rockets, Balloons and Related Space Systems, 7th, Ocean City, MD, Oct. 28-30, 1986. 15 p.
(AIAA PAPER 86-2557)
In order to investigate the potential use of the Space Shuttle as an element of the Canadian Space Science Program, a study has been conducted emphasizing the 'payload of opportunity' NASA payload designation for such systems as the Getaway Specials, the Spartan spacecraft, etc. Attention is given here to the concept of a Flexible Orbiting Carrier Utilizing Shuttle; this is defined as a facility capable of supporting a range of scientific space research over at least the next 10 years. O.C.

**A87-15835#**
**EARTH OBSERVATION COMMITTEE ASSESSMENT**
W. M. STROME (PCI, Inc., Toronto, Canada) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 7 p. refs
(IAF PAPER 86-52)
The role of the Space Station in the future development of earth observations from space is assessed. Earth observations from space are to be utilized to determine the state of the planet at any given time, and to monitor and predict changes. The benefits the Space Station can apply to the study of the atmosphere and meteorology, ocean and coastal observations, and land data are discussed. The polar platform of the Space Station is most useful for earth observation. I.F.

**A87-15837*#** Sundstrand Corp., Rockford, Ill.
**SPACE ENERGY, POWER, AND PROPULSION COMMITTEE ASSESSMENT**
J. P. MULLIN (Sundstrand Corp., Rockford, IL), J. H. AMBRUS (NASA, Washington, DC), P. E. GLASER (Arthur D. Little, Inc., Cambridge, MA), and L. R. SHEPHERD IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 4 p.
(IAF PAPER 86-58)
Energy conversion technology and thermal management for space platforms are addressed using the NASA Space Station as an example. The Space Station IOC configuration includes the use of solar PV and solar dynamic conversion techniques to satisfy the 75-kWe requirement and plans to produce over 300 kWe with the addition of dynamic modules. Nuclear reactors will probably be used to provide the higher energy requirements for future Space Stations in the 1-MW and higher levels. K.K.

**A87-15849*#** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
**EARTH OBSERVING SYSTEM - CONCEPTS AND IMPLEMENTATION STRATEGY**
R. E. HARTLE (NASA, Goddard Space Flight Center, Greenbelt, MD) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. refs
(IAF PAPER 86-72)
The concepts of an Earth Observing System (EOS), an information system being developed by the EOS Science and Mission Requirements Working Group for international use and planned to begin in the 1990s, are discussed. The EOS is designed to study the factors that control the earth's hydrologic cycle, biochemical cycles, and climatologic processes by combining the measurements from remote sensing instruments, in situ measurement devices, and a data and information system. Three EOS platforms are planned to be launched into low, polar, sun-synchronous orbits during the Space Station's Initial Operating Configuration, one to be provided by ESA and two by the United States. I.S.

**A87-15854*#** National Aeronautics and Space Administration, Washington, D.C.

**TECHNOLOGY FOR ACTIVE LASER REMOTE SENSING FROM SPACE**

M. M. SOKOLOSKI (NASA, Washington, DC), F. ALLARIO, and R. R. NELMS (NASA, Langley Research Center, Hampton, VA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 10 p. refs

(IAF PAPER 86-80)

The requirements for the experiments to be performed on the laser atmospheric sounder and altimeter facility of the polar orbiting platform are considered. The proposed instruments for the Lidar In-Space Technology Experiment designed to calibrate and verify the radiative transfer equation for laser energies at wavelengths of 1060, 532, and 355 nm, and to measure the vertical distribution of aerosols, the optical thickness of high altitude clouds, and the top of clouds are described. Research in the area of tunable laser materials and Lidar transmitters, in particular Ti:Al2O3 materials and Lidar transmitters, aimed at increasing wavelength tunability, efficiency, and the lifetime of solid-state lasers for utilization on Space Station polar orbiting platforms is discussed. I.F.

**A87-15972#**

**FACILITIES FOR MICROGRAVITY RESEARCH**

P. VITS and S. WALTHER (MBB/ERNO, Bremen, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p.

(IAF PAPER 86-262)

Facilities for microgravity research are described with attention given to man-tended facilities, automated facilities, free-flying facilities, and Space Station facilities. Various features of the Spacelab program (the basis for the European microgravity program) are discussed as well as those of the TEXUS and MAUS programs (in which NASA Get-Away Special Containers are used). Consideration is also given to Columbus which is an extension of such systems as Spacelab and Eureca. K.K.

**A87-16009#**

**COMPLEX X-RAY OBSERVATORY**

R. Z. SAGDEEV, R. A. SUNIAEV, V. M. BALEBANOV, O. F. PRILUTSKII, A. S. MELIORANSKII (AN SSSR, Institut Kosmicheskikh Issledovanii, Moscow, USSR) et al. IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 14 p.

(IAF PAPER 86-309)

The characteristics and capabilities of the instruments of the wide range X-ray observatory designed to examine sources of cosmic X-ray radiation from the 2-800 keV energy range are described. The payload of the X-ray observatory includes: (1) a hard X-ray spectrometer, (2) an X-ray high-energy scintillation telescope, (3) an X-ray telescope with a coding shadow mask, (4) a gas scintillation proportional spectrometer, (5) a computer, (6) an electronic block to control read out mode, and (7) a filter block. I.F.

**A87-16050#**

**PROBLEMS AND PROSPECTS FOR EDUCATIONAL DIRECT BROADCASTING**

R. CHIPMAN (United Nations, Outer Space Affairs Div., New York) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p.

(IAF PAPER 86-364)

Educational television broadcasting experiments, including projects in India, Brazil, Canada and the United States using direct broadcasting satellites and projects in American Samoa, Niger and Ivory Coast using terrestrial broadcasting, are reviewed. The problems involved in integrating television in educational systems, particularly when the projects are technology driven, are elucidated. The development of an educational television system using satellite transmission in China indicates how some of the obstacles may be overcome. Author

**A87-16092#**

**POLAR PLATFORM COST-EFFECTIVENESS - A EUROPEAN VIEW**

J. A. VANDENKERCKHOVE (VDK System, Brussels, Belgium) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 10 p.

(IAF PAPER 86-438)

Expendable, limited-life, and extendable-life serviceable platforms with expendable spacecraft are compared in terms of life-cycle costs and initial costs. The comparison reveals that serviceable platforms are more cost-effective than expendables; increasing the length of time for limited servicing of the spacecraft from 7.5 to 10 years and decreasing the servicing of the platform over 10 years from 2 to 3 will improve the cost-effectiveness of serviceable platforms. The effects of different transportation systems (Ariane, Hermes, and the Space Shuttle) on the cost of platforms are analyzed. I.F.

**A87-16093#**

**COST EFFECTIVENESS OF POLAR PLATFORM SERVICING**

J. MAJUS, M. TURK, B. BRAND, and J. PULS (DFVLR, Oberpfaffenhofen, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 29 p. refs

(IAF PAPER 86-439)

The cost effectiveness of polar orbiting spacecraft in given utilization scenarios is examined. Life cycle cost comparisons are made for autonomous nonserviceable satellites (e.g., ERS), ground servicing of retrievable carriers (EURECA) derived polar carriers, and in-orbit servicing of platforms (COLUMBUS Polar Platform). It is concluded that cost advantages from in-orbit servicing exist only if servicing intervals do not exceed two years and payload serviceability cost overhead can be kept far lower than assumed. C.D.

**A87-16094#**

**DESIGN AND ECONOMICS OF A FREE-FLYING PLATFORM FOR SPACE MANUFACTURING**

R. BOUDREAULT (Canadian Astronautics, Ltd., Ottawa, Canada) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. Research supported by the Canadian Astronautics, Ltd. refs

(IAF PAPER 86-440)

The utilization of the space environment for materials processing is examined. The costs of support systems for space materials processing, such as the Space Shuttle, Space Station, and free-flying platforms, are evaluated; it is observed that free-flying platforms are cost-effective and are the optimum microgravity support system for a large number of space manufacturing activities. A cost model for free-flying platforms includes project management and administration costs and the recurring and nonrecurring costs for hardware and services such as power systems, thermal control, telemetry and command, reaction control, structure and integration, and launch services. I.F.

**A87-16098#**

**UTILIZATION OF GOVERNMENT INCENTIVES TO PROMOTE COMMERCIAL SPACE STATION DEVELOPMENT**

M. C. SIMON (General Dynamics Corp., Space Systems Div., San Diego, CA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. refs

(IAF PAPER 86-445)

**A87-16113#**

**CONCEPT EVOLUTION OF COMMUNICATION SATELLITES/PLATFORMS IN GEO**

D. E. KOELLE (MBB/ERNO, Ottobrunn, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p. refs

(IAF PAPER 86-464)

The paper analyzes the historical development of communication satellites and platforms in GEO and tries to define 'spacecraft generations' according to the design concept and performance. Specific performance and cost per channel are shown

as historic developments. Concept design criteria are established for spin-stabilized, body-stabilized spacecraft and for future platforms. Author

**A87-16930*#** National Aeronautics and Space Administration, Washington, D.C.

**TELESCIENCE IN ORBIT**

D. C. BLACK (NASA, Office of Space Station, Washington, DC) Aerospace America (ISSN 0740-722X), vol. 24, Sept. 1986, p. 44-46.

A promising concept for the scientific use of the NASA Space Station involves attaching payloads to the dual keel truss structure of the manned base, specifically on the upper and lower booms. The lower boom will be primarily employed by the earth observation and space plasma studies community, while the upper boom will be used by astronomers for such instruments as the Solar Optical Telescope and the Astrometric Telescope Facility. The indispensability of a robust Space Shuttle system for these Space Station uses is noted. O.C.

**A87-17368**

**SPACECRAFT GLOWS FROM SURFACE-CATALYZED REACTIONS**

I. L. KOFSKY and J. L. BARRETT (PhotoMetrics, Inc., Woburn, MA) Planetary and Space Science (ISSN 0032-0633), vol. 34, Aug. 1986, p. 665-681. refs

Existing data on the optical glows that extend from low earth-orbiting spacecraft are shown to be consistent with recombination of ambient atmospheric species on ram-exposed surfaces. Surface-catalyzed exothermic recombination qualitatively explains the reported differences as well as similarities among spacecraft in spectral intensities and spatial distribution of glows, and predicts further emission at ultraviolet, infrared, and to a lesser extent visible, wavelengths. The contextual information concerning such recombination is systematically reviewed with a view to designing experiments which will serve to predict the spectral intensities of optical foregrounds off spacecraft materials exposed to the thermosphere. C.D.

**A87-18324**

**DYNAMICS OF THE ORBITER BASED FLEXIBLE MEMBERS**

V. J. MODI (British Columbia, University, Vancouver, Canada) and A. M. IBRAHIM IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 975-984. refs

(Contract NSERC-A-2181; NSERC-G-0662)

The paper studies libration/vibration interaction dynamics associated with the proposed NASA/Lockheed Solar Array Flight Experiment. Results suggest substantial influence of the inertia parameter, flexural rigidity of the appendages, orbit eccentricity, deployment velocity, initial conditions, etc. on the system response. This would indicate additional demand on the orbiter's control system during construction of space-platforms. Author

**A87-18391**

**RESULTS OF US-JAPAN TETHERED PAYLOAD EXPERIMENT**

K. I. OYAMA, S. SASAKI, N. KAWASHIMA, K. HIRAO (Tokyo, University, Japan), W. J. RAITT (Utah State University, Logan) et al. IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 1493-1499.

The data from a tethered payload experiment conducted on August 14, 1983 in New Mexico, in order to study transient vehicle charging, are discussed. The VLF and HF wave spectra and floating potential are examined. The data reveal that: (1) when the dc electron beam was 80 mA the rocket vehicle became less charged than at 10 mA intensities and strong HF and VLF noise were received; (2) pulsive electron emission gave stronger vehicle charging than dc electron beam emission; and (3) the HF receivers on the daughter rocket became higher as the tether was further separated from the mother rocket. It is noted that the tether system is useful as a simple VLF receiving antenna for futurre rocket and shuttle experiments. I.F.

**A87-18489**

**ON THE ORBITER BASED DEPLOYMENT OF FLEXIBLE MEMBERS**

A. K. MISRA, D. M. XU (McGill University, Montreal, Canada), V. J. MODI (British Columbia, University, Vancouver, Canada; Tokyo, University, Japan), and A. M. IBRAHIM IN: Space exploitation and utilization; Proceedings of the Symposium, Honolulu, HI, December 15-19, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 601-616. refs

(Contract NSERC-67-1547)

(AAS PAPER 85-673)

Using relatively general formulation procedures, the paper attempts to study complex interactions between deployment, attitude dynamics and flexural rigidity for two distinct configurations representing deployment of beam and tether type appendages from the Orbiter. The study suggests that under critical combinations of parameters the systems can become unstable. The results have some relevance to the next generation of communications satellites with large flexible beam type booms and solar panels as well as deployment and retrieval of tethered subsatellite systems. Author

**A87-18495**

**OPTIMAL CONTROL OF COMPONENT DEPLOYMENT FOR THE SPACE RADIOTELESCOPE SYSTEM**

W. STUIVER (Hawaii, University, Honolulu) IN: Space exploitation and utilization; Proceedings of the Symposium, Honolulu, HI, December 15-19, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 679-684.

(AAS PAPER 85-683)

Earlier work (Stuiver et al., 1981, and Stuiver, 1985) on the construction and deployment of a very large space-based radiotelescope for SET1 is extended. The configuration would consist of a self-contained, fully automated antenna system made up of free-floating components. The large spherical reflecting receiver dish would be backed up by an even larger, nominally planar, shield to block electromagnetic radiation. It has been postulated that because of their high area-to-mass ratios the dish and shield would be fabricated at or near GEO altitude and moved by solar sailing to the point of operation. D.H.

**A87-19424**

**POTENTIAL TETHER APPLICATIONS TO SPACE STATION OPERATIONS**

L. GUERRIERO (CNR, Piano Spaziale Nazionale, Rome, Italy) and E. VALLERANI (Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy) (IAF, International Astronautical Congress, 36th, Stockholm, Sweden, Oct. 7-12, 1985) Acta Astronautica (ISSN 0094-5765), vol. 14, 1986, p. 23-32.

(IAF PAPER 85-42)

The range of tether applications is examined from the point of view of related goals and requirements. Proposals for tether applications to the Space Station are reviewed and related studies recently initiated in Italy are described. Applications such as tethered platforms, payload launch and retrieval, and rendezvous and docking are considered in these studies with special attention given to a science and applications tethered platform. K.K.

**A87-19649*** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

**DEVELOPMENT OF THE IMAGING SPECTROMETER FOR SHUTTLE AND SPACE PLATFORM APPLICATIONS**

MARK HERRING and NORMAN A. PAGE (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Instrumentation for optical remote sensing from space; Proceedings of the Meeting, Cannes, France, November 27-29, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 9-16. refs

The concept of the Imaging Spectrometer is becoming established as a major new thrust in remote sensing of the earth.

A future step will be the Shuttle Imaging Spectrometer (SISEX) currently planned for a 1990 flight. This paper describes the current state of development of SISEX, including the development of a modular concept which will allow major elements of SISEX to be used on NASA's Space platform, the Earth Observing System. This modular approach is expected to result in a substantial overall cost saving. Author

**A87-19707**

**ADVANCED OPTO-ELECTRONICAL SENSORS FOR AUTONOMOUS RENDEZVOUS-/DOCKING AND PROXIMITY OPERATIONS IN SPACE**

B. KUNKEL, R. LUTZ, and S. MANHART (Messerschmitt-Boelkow-Blohm GmbH, Munich, West Germany) IN: Solid state imagers and their applications; Proceedings of the Meeting, Cannes, France, November 26, 27, 1985. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 138-148. refs.
138-148. refs

Experimental work on three types of candidate optical sensors for rendezvous and docking tasks, active laser diode radars, CCD cameras and position detector sensors, plus a combination of these is presented. The results obtained up to now with a test lab (including motion simulation) make each of them a promising candidate for this kind of application for different range regimes. These sensors are conceived as multisensor head systems together with a central processing unit to provide applicability beyond docking of space platforms. A description of the sensors, their technical development requirements, achieved performance results, and combination packages, plus a proposal for in-orbit test missions is given. Author

**A87-21320**

**SCIENCE FROM THE SPACE STATION**

JOHN DAVIES Space Education (ISSN 0261-1813), vol. 1, Autumn-Winter 1986/87, p. 560-563.

The impact that the Space Station will have on many fields of science is considered. The main asset of the Space Station to astronomy may ultimately be the ability to assemble large instruments in orbit while microgravity experiments will focus on crystal growth and the preparation of new pharmaceutical products. Experiments in physics and chemistry will involve the search for phenomena predicted by various aspects of relativity theory. It is concluded that maximum involvement on the part of space scientists is essential from the onset of Space Station development. K.K.

**A87-21518#**

**SPACE STATION PLATFORMS - PROPULSION SUBSYSTEM TRADES**

R. T. FECONDA and R. A. RAUSCHER, JR. (RCA, Astro-Electronics Div., Princeton, NJ) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 22nd, Huntsville, AL, June 16-18, 1986. 7 p.
(AIAA PAPER 86-1591)

The propulsion system for the Space Station Platform (SSP) is required to provide initial boost of the platform to operational altitude from STS orbit, attitude control during all thrusting maneuvers, orbit trim, inclination trim, drag make-up, backward attitude control, and deboost of the platform to STS servicing altitude. The propulsion subsystem design must take into account system mass, development cost, contamination effects on spacecraft surfaces and expected payloads, serviceability, and commonality with other Space Station elements, the Orbit Maneuver Vehicle, and STS. Results of a trade study significantly favor earth-storable bipropellants because of their high performance, low weight, and low risk factor. Author

**A87-22416#**

**MODEL FOR RADIATION CONTAMINATION BY OUTGASSING FROM SPACE PLATFORMS**

STEPHEN J. YOUNG and RONALD R. HERM (Aerospace Corp., El Segundo, CA) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 12 p. refs
(Contract F04701-85-C-0086)
(AIAA PAPER 87-0102)

Infrared sensors mounted on space platforms (e.g. Space Shuttle and satellites) may be subject to infrared radiation contamination from molecular gases released from the platform itself. Models for order-of-magnitude estimates of the contamination level caused by this effect are formulated. Application of the model to estimate the effects that the outgassing of H2O from the Shuttle environment would have on the CIRRIS 1A earth-limb radiance mission indicates that detection in the 2.7-micron spectral region would be only slightly degraded, but that detection around 6.3 microns may be seriously impaired by the mechanism of absorption and reemission of earthshine radiation by the H2O contamination molecules. Author

**A87-22554*#** Stanford Univ., Calif.

**SCIENCE IN SPACE WITH THE SPACE STATION**

PETER M. BANKS (Stanford University, CA) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 4 p. Research supported by Stanford University.
(Contract NAGW-0235)
(AIAA PAPER 87-0316)

The potential of the Space Station as a versatile scientific laboratory is discussed, reviewing plans under consideration by the NASA Task Force on Scientific Uses of the Space Station. The special advantages offered by the Station for expanding the scope of 'space science' beyond astrophysics, geophysics, and terrestrial remote sensing are stressed. Topics examined include the advantages of a manned presence, the scientific value and cost effectiveness of smaller, more quickly performable experiments, improved communications for ground control of Station experiments, the international nature of the Station, the need for more scientist astronauts for the Station crew, Station on-orbit maintenance and repair services for coorbiting platforms, and the need for Shuttle testing of proposed Station laboratory equipment and procedures. T.K.

**A87-22555*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

**THE DETECTION OF PLANETARY SYSTEMS FROM SPACE STATION - A STAR OBSERVATION STRATEGY**

ALFRED C. MASCY, KEN NISHIOKA, HELEN JORGENSEN, and BYRON L. SWENSON (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 14 p. refs
(AIAA PAPER 87-0317)

A 10-20-yr star-observation program for the Space Station Astrometric Telescope Facility (ATF) is proposed and evaluated by means of computer simulations. The primary aim of the program is to detect stars with planetary systems by precise determination of their motion relative to reference stars. The designs proposed for the ATF are described and illustrated; the basic parameters of the 127 stars selected for the program are listed in a table; spacecraft and science constraints, telescope slewing rates, and the possibility of limiting the program sample to stars near the Galactic equator are discussed; and the effects of these constraints are investigated by simulating 1 yr of ATF operation. Viewing all sky regions, the ATF would have 81-percent active viewing time, observing each star about 200 times (56 h) per yr; only small decrements in this performance would result from limiting the viewing field. T.K.

**A87-22556*#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.

**EARTH OBSERVING SYSTEM - THE EARTH RESEARCH SYSTEM OF THE 1990'S**

JAMES E. GRAF (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 14 p. NASA-supported research. refs

(AIAA PAPER 87-0320)

The Earth Observing Systems' objective of comprehensively studying the earth's change leads to an array of technological and implementational challenges. Included in those challenges are in the in-orbit maintenance of fifty instruments through periodic servicing and the development of an international ground information system which permits rapid access to high quality data. The paper describes these challenges and also discusses potential contributions from international and USA agencies, mission design and payload groupings strategies, as well as design approaches to the spacecraft itself. Author

**A87-22743#**

**SALTATION THRESHOLD EXPERIMENTS CONDUCTED UNDER REDUCED GRAVITY CONDITIONS**

B. R. WHITE (California, University, Davis), R. GREELEY, R. N. LEACH (Arizona State University, Tempe), and J. D. IVERSEN (Iowa State University of Science and Technology, Ames) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 10 p. refs

(AIAA PAPER 87-0621)

A wind tunnel apparatus was designed as appropriate for use in an orbital Space Station. A scale prototype system was fabricated and its flow characteristics were assessed. Preliminary results show uniform flow and boundary layer properties that are in agreement with theory. Reduced gravity experiments were conducted aboard the KC-135 aircraft in the wind tunnel to determine the saltation threshold friction speed as a function of gravity. The results were compared with the analytical theory and were found to be in reasonable agreement with the theory. The results from this study demonstrate that a wind tunnel of the carrousel design could operate in a Space Station environment and that experiments could be conducted which would yield significant results contributing to the understanding of aeolian processes. Author

**A87-22751*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

**LARGE SPACE OBSERVATORIES OF THE 21ST CENTURY**

M. NEIN, J. HOWELL, S. MORGAN, C. DE SANCTIS (NASA, Marshall Space Flight Center, Huntsville, AL), and D. KOCH (Smithsonian Astrophysical Observatory, Cambridge, MA) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 17 p. refs

(AIAA PAPER 87-0636)

Early in the 21st century, advanced space telescopes will be readied to continue the astronomical observations of the Great Observatories currently under development. This paper describes representative concepts from the very large UV/optical and gamma-ray telescopes under study by NASA, the scientific community, and industry. These studies demonstrate that historical approaches to improving the resolution and sensitivity of space telescopes have reached technology barriers which can only be overcome by innovative solutions to the telescope design. Some of the key technology issues which are guiding the approaches for advanced space telescopes are discussed, and arguments are presented that enabling technology development for these future systems must commence now. Author

**A87-23161#**

**GRAVITY, MICROGRAVITY, AND THE APPROACH TO PICOGRAVITY**

C. W. F. EVERITT (Stanford University, CA) IN: Opportunities for academic research in a low-gravity environment . New York, American Institute of Aeronautics and Astronautics, Inc., 1986, p. 89-119; Comments, p. 121-124. refs

Space gravitation experiments designed to test general relativity theory or measure relativistic effects are surveyed. The prespace history of gravity experiments is traced, and three experiments being developed are described in detail: an orbiting high-precision gyroscope, an orbital version of the Eoetvoes equivalence-principle test, and a twin-satellite experiment. All three are shown to require accelerations constrained to picogravity levels, probably achievable by using a 'flying drop tower' (a free flyer made from a Shuttle main tank) or improving the drag-free performance of satellites (beyond the 5 pg obtained with Discos in the Triad navigation satellites). The goals of these experiments and aspects of their planned realization are discussed in a comment by James E. Faller. T.K.

**A87-23419*** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.

**IDEAS FOR A FUTURE EARTH OBSERVING SYSTEM FROM GEOSYNCHRONOUS ORBIT**

WILLIAM E. SHENK, FORREST HALL, WAYNE ESAIAS, MARVIN MAXWELL (NASA, Goddard Space Flight Center, Greenbelt, MD), VERNER E. SUOMI (Wisconsin, University, Madison), and FRITZ VON BUN (NASA, Office of Space Science and Applications, Washington, DC) IN: Conference on Satellite Meteorology/Remote Sensing and Applications, 2nd, Williamsburg, VA, May 13-16, 1986, Preprints . Boston, MA, American Meteorological Society, 1986, p. 508-513. refs

Uses for the proposed geosynchronous platform are described. The geosynchronous satellite could provide good spatial and temporal resolution, a large field-of-view, easier calibration, stereography, and data relay. The limitations of the platform are discussed. The applications of the geosynchronous platform to meteorology, earth surveying, and oceanography are examined. I.F.

**A87-23420*** Colorado State Univ., Fort Collins.

**PASSIVE MICROWAVE RADIOMETER EXPERIMENT FOR GOES-NEXT**

THOMAS H. VONDER HAAR (Colorado State University, Fort Collins, CO), WILLIAM E. SHENK (NASA, Goddard Space Flight Center, Greenbelt, MD), and DONALD W. GRAUL (Ford Aerospace and Communications Corp., Palo Alto, CA) IN: Conference on Satellite Meteorology/Remote Sensing and Applications, 2nd, Williamsburg, VA, May 13-16, 1986, Preprints . Boston, MA, American Meteorological Society, 1986, p. 514-518.

A new passive microwave radiometer (PMR) experiment for GOES-NEXT is described. The PMR, expected to be in orbit in the early 1990's, is a multichannel microwave radiometer which will allow new measurements of temperature and moisture structure and precipitation by penetrating much of the overlying cloud cover near significant weather systems. PMR experimental objectives are to use a geostationary platform for the first time to obtain passive microwave imagery and soundings in a high time frequency mode to address several scientific objectives. These scientific objectives address current problems of atmospheric science at the mesoscale and in climate research. K.K.

**A87-23985#**

**THRUSTER-AUGMENTED ACTIVE CONTROL OF A TETHERED SUBSATELLITE SYSTEM DURING ITS RETRIEVAL**

A. K. MISRA (McGill University, Montreal, Canada), V. J. MODI (British Columbia, University, Vancouver, Canada), and D. M. XU Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 9, Nov.-Dec. 1986, p. 663-672. refs

(Contract NSERC-A-0967; NSERC-A-2181)

The paper considers control of the rotational motion as well as longitudinal and transverse vibrations of a tethered subsatellite

system during its retrieval to the Shuttle. Control using a set of thrusters alone is studied first; then, a length rate control law augmented by thrusters is examined. The functional forms of the thrust components applicable to both cases are determined by analyzing simplified equations of motion. These are validated by computer simulation of the original equations. The schemes considered appear to be fairly effective in arresting the growth of rotations as well as vibrations while maintaining a nonzero tension in the tether. It is recommended that the exponential retrieval be replaced by uniform retrieval rate toward the end of retrieval. Author

**A87-24198*** Air Force Geophysics Lab., Hanscom AFB, Mass.
**BOOM POTENTIAL OF A ROTATING SATELLITE IN SUNLIGHT**
S. T. LAI, H. A. COHEN (USAF, Geophysics Laboratory, Bedford, MA), T. L. AGGSON (NASA, Goddard Space Flight Center, Greenbelt, MD), and W. J. MCNEIL (Radex, Inc., Carlisle, MA) Journal of Geophysical Research (ISSN 0148-0227), vol. 91, Nov. 1, 1986, p. 12137-12141. refs

An interpretation is provided for the behavior of long boom potential measurements taken on the spinning P78-2 (SCATHA) satellite at near geosynchronous altitudes. This study uses data taken during a quiet day, with the satellite in sunlight. The data show periodic variations with a maximum amplitude of 6 V. The theory explains why the variations correlate well with sun direction but not with the geomagnetic field. A current balance model, assuming a Maxwellian distribution of photoelectrons, is studied. The photoelectron temperature, the degrees of positive charging of the boom and of the satellite, and the ambient electron flux are calculated. Deviations from the model are discussed. Author

**A87-24903#**
**ATTITUDE DYNAMICS OF THREE-BODY TETHERED SYSTEMS**
A. K. MISRA (McGill University, Montreal, Canada), V. J. MODI (British Columbia, University, Vancouver, Canada), and Z. AMIER AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 11 p. Research supported by McGill University and NSERC.
(AIAA PAPER 87-0021)

The dynamics of a tether-connected three-body system is investigated. The system is treated as a double-pendulum and the motion in the orbital plane is considered for the two cases of fixed-length tethers and variable-length tethers. For fixed-length tethers, it is noted that there are four possible equilibrium configurations: both tethers aligned along the local vertical; both tethers horizontal; and for certain combinations of parameters, two other configurations where one tether is along the local vertical while the other is inclined to the local vertical. The vertical equilibrium configuration is stable, the horizontal equilibrium position is unstable, while the other configurations may be stable or unstable depending on the system parameters. Frequencies of oscillations around the stable vertical configuration are given in the paper. The dynamic response of the system during deployment of the three-body constellation is obtained. Dynamical behavior during transportation of a cargo from one end-body to the other is also studied. Author

**A87-25275**
**FLIGHT DYNAMICS OF A SYSTEM OF FLEXIBLY CONNECTED SPACE SYSTEMS [DINAMIKA POLETA SISTEMY GIBKO SVIAZANNYKH KOSMICHESKIKH OB'EKTOV]**
VITALII ALEKSANDROVI IVANOV and IURII STEPANOVICH SITARSKII Moscow, Izdatel'stvo Mashinostroenie, 1986, 248 p. In Russian. refs

Methods for the analysis of the motion of tethered space systems are examined, and some aspects of their practical applications are discussed. Particular attention is given to the study of the qualitative structures and bifurcations of the dynamic systems determining the motion of the tether and characterization of the motion of tethered systems with tethers of constant and adjustable length. The stationary motion of the tether is examined with allowance for its mechanical properties for the case of the sounding of the upper layers of the atmosphere, orbital maneuvers, descent from an orbit, and artificial gravity experiments. V.L.

**A87-25450*#** Boeing Aerospace Co., Seattle, Wash.
**SPACE STATION - IMPLICATIONS FOR SPACE MANUFACTURING**
D. L. TINGEY, H. J. WILLENBERG (Boeing Aerospace Co., Seattle, WA), and H. L. ATKINS (NASA, Marshall Space Flight Center, Huntsville, AL) Pasha Publications, Conference on Space Station: Gateway to Space Manufacturing, Orlando, FL, Nov. 7, 8, 1985, Paper. 17 p.
(Contract NAS8-36122)

Space-based materials processing R&D is examined. It is proposed that the Space Station's Microgravity and Materials Processing Facility will be utilized by academic, government, and commercial customers. Users requirements for materials processing in space are discussed. Consideration is given to the time allocation of the facility, charges to users, and the property rights of the users. I.F.

**A87-25451**
**SPACE STATION: GATEWAY TO SPACE MANUFACTURING; PROCEEDINGS OF THE CONFERENCE, ORLANDO, FL, NOV. 7, 8, 1985**
Conference sponsored by Pasha Publications. Arlington, VA, Pasha Publications, 1985, 437 p. For individual items see A87-25452 to A87-25461.

Opportunities for commercial manufacturing operations on the Space Station are discussed in reviews and reports by NASA and industry experts. Topics examined include private initiatives and opportunities, promising new technologies, low-cost starting options, new types of space-operations financing, and initial space laboratories and factories. Extensive diagrams, tables, and drawings are provided. T.K.

**A87-25452#**
**SPACE INDUSTRIES' INDUSTRIAL SPACE FACILITY AND THE U.S. SPACE STATION PROGRAMS**
MAXIME A. FAGET (Space Industries, Inc., Houston, TX) IN: Space Station: Gateway to space manufacturing; Proceedings of the Conference, Orlando, FL, Nov. 7, 8, 1985 . Arlington, VA, Pasha Publications, 1985, 19 p.

The expansion of commercial space materials-research and manufacturing opportunities with the deployment of the Space Station is discussed, and a Station-compatible industrial space facility (ISF) being developed for deployment before the Station becomes commercially available is described and illustrated with drawings. The ISF is based on a shirtsleeve-environment module of length 35 ft, diameter 14.5 ft, and internal volume 2500 cu ft, designed to be launched on one Shuttle flight to a circular orbit with inclination 28 deg and altitude 230 n. mi.; each module is capable of fully independent operation. It is predicted that the most important cost factor for space production will continue to be the transportation cost, so that only high-value materials such as semiconductor crystals and pharmaceuticals can be produced profitably; the need for further government subsidization of space-transportation costs is indicated. T.K.

**A87-25461*#** Teledyne Brown Engineering, Huntsville, Ala.
**DEFINING A NATIONAL MICROGRAVITY FACILITY FOR AMERICA'S SPACE STATION**
TRIPTY MOOKHERJI, A. SHARPE, and ERNST STUHLINGER (Teledyne Brown Engineering, Huntsville, AL) IN: Space Station: Gateway to space manufacturing; Proceedings of the Conference, Orlando, FL, Nov. 7, 8, 1985 . Arlington, VA, Pasha Publications, 1985, 35 p.
(Contract NAS8-36122)

Plans for a Microgravity and Materials Processing Facility (with a Manufacturing and Technology Laboratory Module as its main element) on the U.S. Space Station are reviewed and illustrated with drawings, graphs, tables, and diagrams. Consideration is given to the ideal and practically achievable acceleration environment,

on-orbit sample preparation and analysis, crew operations, technology-development requirements, and classes of materials with commercial potential (with an emphasis on organic molecular crystals). T.K.

**A87-25698**
**ON VIBRATIONS OF ORBITING TETHERS**
A. K. MISRA (McGill University, Montreal, Canada), V. J. MODI (British Columbia, University, Vancouver, Canada), and D. M. XU Acta Astronautica (ISSN 0094-5765), vol. 13, Oct. 1986, p. 587-597. refs
(Contract NSERC-A-0967; NSERC-A-2181)

The paper considers three-dimensional transverse and longitudinal oscillations of a tether connecting a subsatellite to the Shuttle. Attention is focused on the dynamics during the terminal phase of retrieval of the subsatellite. Nonlinearity in the strain-displacement relation is taken into account since it is important and helpful during this phase. Retrieval schemes that can assist in arresting the growth of vibrations are obtained by simplified analysis and validated through numerical solution of the original equations. Author

**A87-25754**
**THE FREE FLYING PLATFORM**
E. P. L. WINDSOR (British Aerospace, PLC, Space and Communications Div., Bristol, England) IN: Space Tech '86; Proceedings of the International Conference, Geneva, Switzerland, May 14-16, 1986 . London, Online International, Ltd., 1986, p. 33-43.

The role of free flying platform in a Manned Space Station is discussed, and some of the aims and constraints in the design of such systems discussed. In particular, the main features of the Polar platform being studied for ESA's Columbus Programme are described. It is concluded that such systems can provide substantial advantages to the user community. Author

**A87-25833**
**ROBUS - A RETRIEVABLE TELESCOPE CARRYING PLATFORM BASED ON ROSAT EXPERIENCE**
NORBERT PAILER, ROLF DIETER AUER, and EDGAR BACHOR (Dornier System GmbH, Friedrichshafen, West Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 10, Sept.-Oct. 1986, p. 338-348.

Rosat is a scientific satellite designed for a mission to provide major advances in X-ray astronomy. In the first stage of its mission, Rosat will systematially scan the sky for X-ray sources so that, for the first time, a complete X-ray map of the celestial sphere can be produced. The second stage is dedicated to the observatin of selected X-ray sources, which can be localized with an accuracy better than 10 arcsec, depending on the characteristics of the source observed and on the focal instrument used. The largest imaging Wolter type telescope built to data allows the measurement of soft X-rays in the 6-120-A region with high sensitivity and high resolution. Taking advantage of the experience compiled in the Rosat project, attention is being concentrated on plans to utilize the Rosat bus for future scientific missions. With the Rosat satellite as starting point, the Robus platform (retrievable orbiting bus) has been developed. Three Robus configurations are envisaged for different types of missions. The concept of a retrievable free-flying platform significantly broadens the potential future use scenario of space shuttles and space stations. As a consequence of the Shuttle situation and to provide independence from the Shuttle, the possibility of launching Robus on expendable launch vehicles is discussed. Author

**A87-25834**
**THE TETHERED SATELLITE SYSTEM - PRESENT STATUS AND FUTURE DEVELOPMENTS**
ALBERTO ANSELMI and FRANCESCO GIANI (Aeritalia S.p.A., Turin, Italy) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 10, Sept.-Oct. 1986, p. 349-356. refs

The Tethered Satellite System (TSS), a joint venture between NASA and the Italian Space Agency (PSN/CNR), is presented. Details are given of the first (electro-dynamic) mission, planned for 1988, the design of which is currently being finalized in terms of deployment means, satellite and scientific payload. Emphasis is given to the satellite, which is designed for reusability on a wide range of missions and applications. Further flights of the TSS, notably the second (atmospheric) mission, are also considered. A survey of promising ideas for the future use of tethered satellites, including application to the projected Space Station, is then given. Author

**A87-26060**
**ACOUSTIC CLEANING OF LARGE SPACE STRUCTURES**
J. BUSH, L. AGUILAR, and S. KWAN (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: Institute of Environmental Sciences, Annual Technical Meeting, 32nd, Dallas and Fort Worth, TX, May 6-8, 1986, Proceedings . Mount Prospect, IL, Institute of Environmental Sciences, 1986, p. 493-500.

Two sets of acoustic experiments related to contamination control of the Hubble Space Telescope modules are reported. In the particle distribution experiments, the maximum fallout from the vertical one square foot source was 64 inches horizontally away from the wall, and the 139 dB experiment resulted in a maximum fallout six inches away from the vertical surface. The experiment dealing with the acoustic cleaning of a Light Shield Test Specimen (LSTS) indicated that cleaning in a horizontal attitude during acoustic exposure results in lower surface level particulate count, but shows the same particulate fallout as the LSTS in the vertical orientation. R.R.

**A87-27507**
**FIRST INTEGRALS OF MOTION IN THE DYNAMICS OF TETHERED SATELLITES**
MAHESH RAJAN (Arizona State University, Tempe) and T. J. ANDERSON (Space Data Corp., Tempe, AZ) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 34, July-Sept. 1986, p. 331-339. refs
(Contract NSF MEA-85-05096)

First integrals of motion in the planar librational deployment/retrieval dynamics of Shuttle-Tethered-Subsatellite systems are derived using Noether's theorem. The first integrals are useful in understanding the librational dynamics described by a nonautonomous equation of motion. The first integrals are used to investigate the stability of the system by Liapunov's second method. Author

**A87-27604#**
**RESUPPLY MODELS FOR SPACE LOGISTICS AND INFLUENCE ON DESIGN**
MEHRAN SEPEHRI (Southern California, University, Los Angeles, CA) IN: Space Logistics Symposium, 1st, Huntsville, AL, Mar. 24-26, 1987, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1987, p. 1-4.
(AIAA PAPER 87-0657)

A 40:1 benefits/costs ratio projected for space manufacturing depends to a large degree on the use of long-duration, repairable, reusable platforms. Reusability would somewhat ameliorate the financial requirements for space ventures, and would permit reconfiguration of the platforms for different missions. The capability of servicing spacecraft on-orbit requires a systems approach to control higher costs of platforms which will have mission flexibility. Repair and changeout options must be known in advance and identifiable prior to manned servicing flights. Design engineering techniques are discussed for deriving optimum economic balances for given level of availability relative to projected costs. Monte

Carlo modeling is recommended for simulating the maintenance of space platforms. The simulation must also allow minimization of inventory and spare parts. M.S.K.

**A87-27606#**

**A MODEL FOR ENVELOPING SPACE STATION LOGISTICS REQUIREMENTS**

K. M. SEISER and R. E. GIUNTINI (Wyle Laboratories, Huntsville, AL) IN: Space Logistics Symposium, 1st, Huntsville, AL, Mar. 24-26, 1987, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1987, p. 12-20.
(AIAA PAPER 87-0659)

The methods used and results obtained from a logistics analysis of the requirements for the NASA Materials and Technology Laboratory (MTL) module of the Space Station are summarized. The MTL will have facilities for basic and applied research in processing fluids, biological, electronic, chemical, glass, ceramic, and metallic materials and combustion science. The rack-mounted equipment will have standardized interfaces to permit changeouts as desired to accommodate new studies. Quantitative techniques used in logistics analysis to identify the traffic procedures and facilities necessary to maintain flight-ready hardware, hardware in-orbit, and groundside equipment deintegration operations that would maximize MTL utilization are discussed. Methods used to include consideration of crew utilization and the required consumables to ensure that all payloads would receive adequate runtimes are also described. M.S.K.

**A87-28558**

**IDENTIFICATION, APPLICATIONS, AND DYNAMIC ANALYSIS OF NONLINEAR SPACECRAFT COMPONENTS**

INGO KOLSCH and HORST BAIER (Dornier System GmbH, Friedrichshafen, West Germany) IN: International Modal Analysis Conference, 4th, Los Angeles, CA, Feb. 3-6, 1986, Proceedings. Volume 1 . Schenectady, NY, Union College, 1986, p. 720-729. refs

Techniques for the dynamical analysis of spacecraft structures with nonlinear components are discussed, considering both undesirable nonlinearities (such as joint stiffness and bearing play) and designed nonlinearities (such as dampers and shock absorbers to isolate delicate equipment from launch or on-orbit accelerations). The sine-vibration testing, harmonic-balance analysis, and Fourier-approximation analysis (to account for quasi-static accelerations) of an actuator-bearing/solar-panel assembly for the TV-Sat/TDF-1 communication satellite are described and illustrated with graphs and diagrams. Good agreement between model predictions and test measurements is demonstrated, and problems in determining the stiffness coefficients and evaluating the damping are indicated. T.K.

**A87-28952**

**THE SPACE STATION IN CHEMICAL AND PHARMACEUTICAL RESEARCH AND MANUFACTURING**

M. J. LEGGETT (Caribonum, Ltd., Turriff, Scotland) British Interplanetary Society, Journal (Space Stations) (ISSN 0007-084X), vol. 40, Jan. 1987, p. 11-18. refs

This paper examines materials processing in space and microgravity research in the chemical and pharmaceutical sciences in relation to Space Station exploitation. Current industrial activity, and some potential future activity, in several areas of chemistry are discussed. These areas include inorganic and organic chemistry (fluids, polymers, and free radicals), applied solid state chemistry and molecular electronics (crystal growth for electronics, radiation detectors, and electro-optical devices) and medicinal/pharmaceutical chemistry (protein crystal growth and drug design). The scientific and economic importance of these areas is also discussed. User and operational requirements for chemical and pharmaceutical utilization of the Space Station are also briefly discussed. These include justification for the manned Space Station, user requirements, health and safety, and space commercialization. The potential of space processing lies initially in research. Such research could be performed in support of ground-based research, or applied to optimize earth-based processes. Microgravity research should also identify products, probably fine chemicals, that can only be manufactured in space. Author

**A87-28957**

**SPACE STATION APPLICATIONS - AN ASSESSMENT OF OPPORTUNITIES IN BIOTECHNOLOGY**

MARTIN J. FOWLER (Molecular Genetics Laboratory, Porton Down, England) British Interplanetary Society, Journal (Space Stations) (ISSN 0007-084X), vol. 40, Jan. 1987, p. 43-48. refs

Opportunities for commercial biotechnology in space are examined. The present status, potential advances, and problem areas in terrestrial biotechnology are discussed. Space-based bioprocessing may contribute to the solution of problems in the purification of desired protein and cell products produced by both recombinant DNA and traditional methods. Consideration is given to electrophoresis, two-phase partitioning, large-scale cell cultivation, and protein crystallization. I.F.

**A87-29407**

**SPACE COMMERCIALIZATION IN THE USA**

PETER WRIGHT WOOD (Booz, Allen, and Hamilton, Inc., Arlington, VA) IN: Space commerce '86; Proceedings of the International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, June 16-20, 1986 . Geneva, Interavia Publishing Group, 1986, p. 48-56.

Near-term growth of space industries in the U.S. will probably occur in materials processing, the manufacture of launch vehicles and Shuttle and Space Station components, and remote sensing products. Space industries growth will depend on access to space, the costs of access, market identification and government policies. Recent initiatives include an emphasis on automation, AI and robotics systems for the Space Station and free-flyers, aerospace consortia work on microgravity materials processing, a NASA contract for a new privately-developed Transfer Orbit Stage for the Mars Observer Mission, the opening of five NASA Centers for the Commercial Development of Space, and private development of a SPACEHAB for enlarging the mid-deck living and experiment volume on the Orbiter. A National Commission on Space has furnished the Administration with a blueprint for U.S. space activities into the beginning of the 21st century, when Mars exploration, closed ecology space habitats and asteroid exploitation could begin. M.S.K.

**A87-30880*** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.

**NASA'S LIFE SCIENCES PROGRAM**

GERALD A. SOFFEN (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Space science and applications: Progress and potential . New York, IEEE Press, 1986, p. 55-68.

NASA space missions from the Mercury through the Shuttle program have provided successively more data on the ability of humans to function in space for progressively longer periods of time. The Skylab program encouraged cooperation between medical and engineering personnel in the design of space suits, diet, food preparation, and cleanliness procedures and equipment, and the man-machine interface. Research is now concentrated on supporting man in space, evaluating the effects of the microgravity environment on humans, and modeling encounters with extraterrestrial life and the effects of human activities on terrestrial biota. Current levels of understanding of the physiological causes of human health problems produced by long-duration spaceflight are summarized. Experiments planned for the Shuttle, Spacelab, and the Space Station are outlined, noting the long-term goal of configuring the Space Station so that only food and hydrazine are needed to complete the life support system cycle. M.S.K.

**A87-31103*#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.
**EARTH OBSERVING SYSTEM INSTRUMENT POINTING CONTROL MODELING FOR POLAR ORBITING PLATFORMS**
H. C. BRIGGS, T. KIA, S. A. MCCABE, and C. E. BELL (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 15 p. refs
(AIAA PAPER 87-0022)

An approach to instrument pointing control performance assessment for large multi-instrument platforms is described. First, instrument pointing requirements and reference platform control systems for the Eos Polar Platforms are reviewed. Performance modeling tools including NASTRAN models of two large platforms, a modal selection procedure utilizing a balanced realization method, and reduced order platform models with core and instrument pointing control loops added are then described. Time history simulations of instrument pointing and stability performance in response to commanded slewing of adjacent instruments demonstrates the limits of tolerable slew activity. Simplified models of rigid body responses are also developed for comparison. Instrument pointing control methods required in addition to the core platform control system to meet instrument pointing requirements are considered. Author

**A87-31134*#** Martin Marietta Corp., Denver, Colo.
**PROPULSION RECOMMENDATIONS FOR SPACE STATION FREE FLYING PLATFORMS**
L. R. REDD and L. J. ROSE (Martin Marietta Corp., Denver, CO) Joint Army-Navy-NASA-Air Force Interagency Propulsion Committee, Propulsion Conference, New Orleans, LA, Aug. 27, 1986, Paper. 24 p.
(Contract NAS3-23893)

Propulsion system candidates have been defined for Space Station free flying platforms for the purpose of comparison and to understand the impact of the various mission requirements on the candidate designs. Consideration of the platform mission requirements and comparisons of the conceptual propulsion system design candidates has led to a fairly clear set of recommendations for propulsion for each of the various platforms. Author

**A87-31211*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**PLASMA CONTACTORS FOR ELECTRODYNAMIC TETHERS**
MICHAEL J. PATTERSON (NASA, Lewis Research Center, Cleveland, OH) and PAUL J. WILBUR (Colorado State University, Fort Collins) Aerospace America (ISSN 0740-722X), vol. 25, Feb. 1987, p. 32-34.

Plasma contactors could be used to ground satellites to space plasma to acquire a flow of electrons to propel or power the satellites. A tether would cut across geomagnetic field lines, producing a potential difference between the ends of the tether. Closing the connection between the ends would form a circuit in which an electrical load could be inserted. Design constraints of the circuit are low impedance and a fully reversible high current. The contactor would generate a neutral plasma to connect to the ionospheric plasma. The surface area of the connection would have to be kept large enough for the current density to be equal to the random electron current density in the unperturbed space plasmas. The other contactor would feed electrons and draw ions from the space plasma. Experimental results from spaceborne and ground-based space plasma simulator tests of hollow cathodes that have shown that multiampere currents can be collected are described. M.S.K.

**N87-10113** Centre National d'Etudes Spatiales, Toulouse (France).
**PROCEEDINGS OF AN INTERNATIONAL CONFERENCE ON SPACE DYNAMICS FOR GEOSTATIONARY SATELLITES**
1986 869 p In ENGLISH and FRENCH Conference held in Toulouse, France, Oct. 1985
(ISBN-2-85428-149-7; ETN-86-98079) Avail: CEPADUES-Editions, 111 rue Nicolas-Vauquelin, 31100 Toulouse, France

Geostationary satellite mission analysis, attitude determination, orbit determination, (onboard technology, low-thrust techniques, station acquisition, stationkeeping) ground segments, and future developments were discussed. ESA

**N87-10169*#** Energy Science Labs., Inc., San Diego, Calif.
**GUIDEBOOK FOR ANALYSIS OF TETHER APPLICATIONS Final Report**
J. A. CARROLL Mar. 1985 47 p
(Contract NAS8-35499)
(NASA-CR-178904; NAS 1.26:178904) Avail: NTIS HC A03/MF A01 CSCL 22A

This guidebook is intended as a tool to facilitate initial analyses of proposed tether applications in space. The guiding philosophy is that a brief analysis of all the common problem areas is far more useful than a detailed study in any one area. Such analyses can minimize the waste of resources on elegant but fatally flawed concepts, and can identify the areas where more effort is needed on concepts which do survive the initial analyses. The simplified formulas, approximations, and analytical tools included should be used only for preliminary analyses. For detailed analyses, the references with each topic and in the bibliography may be useful. B.G.

**N87-10174*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**COAXIAL TUBE TETHER/TRANSMISSION LINE FOR MANNED NUCLEAR SPACE POWER Patent Application**
D. J. BENTS, inventor (to NASA) 18 Aug. 1986 15 p
(NASA-CASE-LEW-14338-1; US-PATENT-APPL-SN-897239; NAS 1.71:LEW-14338-1) Avail: NTIS HC A02/MF A01 CSCL 10B

A spacecraft comprising a platform, a power system and a power transmission line adapted to transmitting high voltage electrical power in a space environment is disclosed. The transmission power line tethers the suborbiting platform to the power system located in a superorbital position relative to the platform. NASA

**N87-10265*#** National Aeronautics and Space Administration, Washington, D.C.
**LIDAR REMOTE SENSING FROM SPACE: NASA'S PLANS IN THE EARTH SCIENCES**
R. J. CURRAN *In* NASA. Langley Research Center 13th International Laser Radar Conference 1 p Aug. 1986
Avail: NTIS HC A15/MF A01 CSCL 20E

A multidisciplinary study of the Earth System to provide a better understanding of the complex interrelated processes involved in the system, the Earth Observing System (EOS), is being developed. Capabilities of the Space Station, both the polar orbiting platform and the lower inclination platforms, will be used to accommodate a number of large active and/or passive sensors. Two lidar instruments being considered as part of the Eos payload are the Lidar Atmospheric Sounder and Altimeter (LASA) and the Laser Atmospheric Wind Sounder (LAWS). The LASA instrument is separable into two portions: the atmospheric sounder component and the retroranging component. The LASA atmospheric sounder will sample the spatial distribution of several atmospheric parameters. The retroranging component will be used to determine the precise three-dimensional position of specifically placed retro-reflectors and to sense how these retro-reflectors change position over monthly to yearly time periods. The LAWS utilizes a lidar system capable of measuring the Doppler shift in the

backscattered intensity to determine the wind velocity profile. B.G.

**N87-10926#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.
**LOADS ANALYSIS FOR THE GALILEO SPACECRAFT**
M. TRUBERT *In* ESA Proceedings of an International Conference on Spacecraft Structures p 293-298 Apr. 1986
Avail: NTIS HC A19/MF A01

The loads analysis for the design of the Galileo structure was done by combining the transient analysis method with methods aimed at reducing cost and schedule impact while increasing confidence in the estimation of the loads. The preliminary sizing was done by the mass acceleration curve. The loads iterations were done by the generalized shock spectra method. Only a few critical subsystems required a coupled transient analysis to show positive margins. Dynamic coupling between the launch vehicle and the spacecraft was done by analytically removing and adding a spacecraft to a given launch vehicle at the modal level, without re-solving the eigenvalue problem. The modal response resulting from the dynamic coupling between the launch vehicle and the spacecraft was used only for the 28 Galileo modes below 40 Hz. In the absence of definition of the Shuttle/Centaur model and the forcing functions above 40 Hz, the mass acceleration curve was used to generate modal bounds between 40 and 80 Hz. ESA

**N87-10944*#** Energy Science Labs., Inc., San Diego, Calif.
**GUIDEBOOK FOR ANALYSIS OF TETHER APPLICATIONS Final Report**
J. A. CARROLL Feb. 1985 47 p
(Contract NAS8-35499)
(NASA-CR-178903; NAS 1.26:178903) Avail: NTIS HC A03/MF A01 CSCL 22A

This guidebook is intended as a tool to facilitate initial analyses of proposed tether applications in space. Topics disscussed include: orbit and orbit transfer equations; orbital perturbations; aerodynamic drag; thermal balance; micrometeoroids; gravity gradient effects; tether control strategies; momentum transfer; orbit transfer by tethered release/rendezvous; impact hazards for tethers; electrodynamic tether principles; and electrodynamic libration control issues. B.G.

**N87-11815*#** Smithsonian Astrophysical Observatory, Cambridge, Mass.
**ANALYTICAL INVESTIGATION OF THE DYNAMICS OF TETHERED CONSTELLATIONS IN EARTH ORBIT, PHASE 2 Quarterly Report, 22 Jun. - 21 Sep. 1986**
E. C. LORENZINI, D. A. ARNOLD, M. COSMO, and M. D. GROSSI Oct. 1986 59 p
(Contract NAS8-36606)
(NASA-CR-178953; NAS 1.26:178953; QR-6) Avail: NTIS HC A04/MF A01 CSCL 22A

The following topics related to the dynamics of the 4-mass tethered system are addressed: (1) the development of damping algorithms for damping the out-of-plane libration of the system and the interaction of the out-of-plane control with the other degrees of freedom; and (2) the development of environmental models to be added to the dynamics simulation computer code. The environmental models are specifically a new drag routine based on the Jacchia's 1977 model, a J(2) model and an accurate thermal model of the wire. Regarding topic (1) a survey of various out-of-plane libration control laws was carried out. Consequently a yo-yo control law with amplitude of the tether length variation proportional to the amplitude of the out-of-game libration has been selected. This control law provides good damping when applied to a (theoretical) two-dimensional system. In the actual 3-dimensional 4-mass tethered system, however, energy is transferred to the least damped degrees of freedom (the out-of-plane lateral deflections are still undamped in the present simulations) in such a way as to decrease the effectiveness of the algorithm for out-of-plane libration control. The addition of damping algorithms for the out-of-plane lateral deflections is therefore necessary. M.G.

**N87-12604#** Naval Research Lab., Washington, D.C.
**THE SPACE STATION MILLIMETER FACILITY**
K. W. WEILER, B. K. DENNISON, R. M. BEVILACQUA, J. H. SPENCER, and K. J. JOHNSTON 9 Jun. 1986 58 p
(AD-A168983; NRL-MP-5794) Avail: NTIS HC A04/MF A01 CSCL 22B

A large millimeter wavelength interferometer array is proposed for construction on the planned Space Station (The Space Station Millimeter Facility--SSMF). It will have manifold applications in both basic and applied research and will be the premier instrument in the world at high radio frequencies. Earth resource mapping, middle atmospheric studies, and high frequency radio astronomy are only a few of the areas which will be significantly advanced by the availability of such an instrument. Particularly in astronomy, the ability to do observations above the disturbing and absorbing effects of the Earth's atmosphere will allow opportunities for exploration of all objects from the Sun, through the Solar System bodies, to the interstellar medium of the Milky Way and other galaxies, and out to the most distant quasars with resolution and sensitivity equalling or exceeding all existing or planned millimeter wavelength telescopes. One of the last unexplored regions of the electromagnetic spectrum, the mm-IR gap, can finally be closed. A flexible design for the SSMF is proposed, and estimate of its construction costs is made, and numerous scientific applications in a number of disciplines are discussed. GRA

**N87-12609*#** Stanford Univ., Calif. Space, Telecommunications and Radio Science Lab.
**HIGH VOLTAGE CHARACTERISTICS OF THE ELECTRODYNAMIC TETHER AND THE GENERATION OF POWER AND PROPULSION Final Report**
P. R. WILLIAMSON 23 Jan. 1986 15 p
(Contract NAS8-35502)
(NASA-CR-178949; NAS 1.26:178949) Avail: NTIS HC A02/MF A01 CSCL 10B

The Tethered Satellite System (TSS) will deploy and retrieve a satellite from the Space Shuttle orbiter with a tether of up to 100 km in length attached between the satellite and the orbiter. The characteristics of the TSS which are related to high voltages, electrical currents, energy storage, power, and the generation of plasma waves are described. A number of specific features of the tether system of importance in assessing the operational characteristics of the electrodynamic TSS are identified. B.G.

**N87-13047*#** Simpson Weather Associates, Inc., Charlottesville, Va.
**MULTISCALE MODELING TO EVALUATE PROPOSED SPACE-BASED DOPPLER LIDAR SAMPLING STRATEGIES**
G. D. EMMITT *In* NASA. Marshall Space Flight Center NASA/MSFC FY-85 Atmospheric Processes Research Review 2 p Oct. 1985
Avail: NTIS HC A07/MF A01 CSCL 04B

A proposal has been made to place a pulsed Doppler lidar on a space platform (Huffaker, et al., 1980; Emmitt, 1982) in a low earth orbit (200 to 800 km) to measure the atmospheric winds with a spatial resolution commensurate with the current continental rawinsonde network density - i.e., 300 to 500 km resolution. In the case of the space-based doppler lidar, the full range of space scales applies. Single shot pulses with dimensions of 10 x 1000 meters are used to sample areas 100,000 x 100,000 meters to resolved mass flow structure with wavelength of 1 million meters. Simulation studies, therefore, require an equally broad range of atmospheric models. A general circulation model is appropriate to answer questions regarding the impact of a global wind measuring system upon synoptic forecasts. Since the nominal resolution of the spacebased system is expected to be a few 100's of kilometers, then a numerical model with mesoscale dynamics is required. The meaning of an average Doppler shift within a laser pulse volume must be evaluated with models of turbulent/convective scale motions and aerosol gradients. Examples of how models on all these scales have been applied in an ongoing simulation study are presented. In particular, the uncertainties in a mesoscale wind estimate are separated into those arising from pulse scale variances

and those due to sample distribution within a prescribed resolution volume. Trade-offs between accuracy and representativeness are discussed in terms of the model results. Author

**N87-13466*#** Draper (Charles Stark) Lab., Inc., Cambridge, Mass.
**FORMATIONKEEPING OF SPACECRAFT VIA DIFFERENTIAL DRAG M.S. Thesis**
C. L. LEONARD 1 Jul. 1986 159 p Prepared for Massachusetts Inst. of Tech., Cambridge
(Contract NAS9-17560)
(NASA-CR-171939; NAS 1.26:171939; CSDL-T-920) Avail: NTIS HC A08/MF A01 CSCL 22A

The use of differential drag in the formationkeeping of spacecraft is examined. In many future space missions one satellite will be required to fly in a specific position with respect to another satellite; this action is referred to as formationkeeping. In this study, differential drag is the difference in drag between the two satellites. Reasons to use differential drag as an actuator for formationkeeping include the avoidance of jet plume impingement effects on closely spaced satellites and possible fuel savings. The equations of relative motion between the two satellites are derived and a mathematical transformation is made to reduce the formationkeeping problem to the simultaneous solution of a double integrator and a harmonic oscillator. A two part control law is developed that simultaneously and dependently solves cases being driven to a target position; two different simulations are used. The validity of assumptions made in the derivation of the control law is examined in the comparison of similar test cases run through different simulations. The control law developed can drive a satellite from an initial position to a target position and maintain the satellite at that location. Author

**N87-13475*#** Alabama Univ., Huntsville.
**GETAWAY TETHER EXPERIMENT (GATE): A FREE FLYING TETHER EXPERIMENT Final Report**
M. GREENE Dec. 1986 68 p
(Contract NAG8-586)
(NASA-CR-179912; NAS 1.26:179912) Avail: NTIS HC A04/MF A01 CSCL 22B

Orbital reboost and power generation using electrodynamic tethers has been suggested as a means of increasing the operational flexibility and orbital lifetime of satellites. Excess energy generated by solar arrays can be stored as orbital energy and later extracted form the orbit during peak power demands. The Getaway Tether Experiment (GATE) will demonstrate this practical tether application and will measure the dynamic circuit impedance. The micrometeoroid hazard to tension members will be studied as will radio frequency propagation. The radar cross section of long wires will be calculated considering the effects of resistance. E.R.

**N87-14364#** SATCOM International, Paris (France).
**ANALYSIS OF RENDEZVOUS AND DOCKING IN GEOSTATIONARY EARTH ORBIT. RIDER TO COMPARISON OF FUTURE COMMUNICATIONS SPACE SEGMENT CONCEPTS Final Report**
C. COUGNET, J. M. AUBERTIN, P. LEBOUAR, B. GOVIN, A. AYOUN, and M. CALDICHOURY Toulouse, France Matra Espace Sep. 1982 164 p
(Contract ESA-4818/81-NL-MD)
(DM51-C/PL/FL/0099.82; ESA-CR(P)-2011-VOL-2; ETN-87-98644) Avail: NTIS HC A08/MF A01

Geostationary rendezvous homing, final approach, and docking phases were analyzed. The target is assumed to be a linear telecommunication platform composed of a service module and several payload modules; when operating, the platform must not be disturbed by the rendezvous and docking (RVD) operations. A period of time compatible with the orientation of the solar arrays is allocated each day for the final approach and docking phase. The homing phase and final approach are analyzed with simulations which propose a nominal strategy to meet the constraints and requirements, and to reuse as much as possible hardware already implemented on board. The analysis of docking phase is performed in terms of performance and requirements, and results in the definition of docking mechanism concepts. Block diagram of the RVD is compared to the reference scenario; the applicability of the scenario to ESAS platform and specific RVD hardware are discussed. ESA

**N87-14375*#** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
**REPORT ON SMRM C/P MAIN ELECTRONIC BOX COMPONENT AND MATERIALS DEGRADATION EVALUATIONS**
R. E. DAVIS *In its* Proceedings of the SMRM Degradation Study Workshop p 33-40 1985
Avail: NTIS HC A16/MF A01 CSCL 22B

The history of the Main Electronics Box (MEB), a description of the the assembly, and handling conditions following the Solar Maximum Repair Mission are contained. B.G.

**N87-14687*#** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
**THE GEOSCIENCE LASER ALTIMETRY/RANGING SYSTEM (GLARS)**
S. C. COHEN, J. J. DEGNAN, J. L. BUFTON, J. B. GARVIN, and J. B. ABSHIRE Sep. 1986 19 p
(NASA-TM-87803; REPT-87B0018; NAS 1.15:87803) Avail: NTIS HC A02/MF A01 CSCL 20E

The Geoscience Laser Altimetry Ranging System (GLARS) is a highly precise distance measurement system to be used for making extremely accurate geodetic observations from a space platform. It combines the attributes of a pointable laser ranging system making observations to cube corner retroreflectors placed on the ground with those of a nadir looking laser altimeter making height observations to ground, ice sheet, and oceanic surfaces. In the ranging mode, centimeter-level precise baseline and station coordinate determinations will be made on grids consisting of 100 to 200 targets separated by distances from a few tens of kilometers to about 1000 km. These measurements will be used for studies of seismic zone crustal deformations and tectonic plate motions. Ranging measurements will also be made to a coarser, but globally distributed array of retroreflectors for both precise geodetic and orbit determination applications. In the altimetric mode, relative height determinations will be obtained with approximately decimeter vertical precision and 70 to 100 meter horizontal resolution. The height data will be used to study surface topography and roughness, ice sheet and lava flow thickness, and ocean dynamics. Waveform digitization will provide a measure of the vertical extent of topography within each footprint. The planned Earth Observing System is an attractive candidate platform for GLARS since the GLAR data can be used both for direct analyses and for highly precise orbit determination needed in the reduction of data from other sensors on the multi-instrument platform. (1064, 532, and 355 nm)Nd:YAG laser meets the performance specifications for the system. Author

**N87-14771*#** Sverdrup Technology, Inc., Cleveland, Ohio.
**CONCEPTUAL DEFINITION OF A TECHNOLOGY DEVELOPMENT MISSION FOR ADVANCED SOLAR DYNAMIC POWER SYSTEMS Final Report**
R. P. MIGRA Jul. 1986 128 p
(Contract NAS3-24105)
(NASA-CR-179482; E-3132; NAS 1.26:179482) Avail: NTIS HC A07/MF A01 CSCL 10B

An initial conceptual definition of a technology development mission for advanced solar dynamic power systems is provided, utilizing a space station to provide a dedicated test facility. The advanced power systems considered included Brayton, Stirling, and liquid metal Rankine systems operating in the temperature range of 1040 to 1400 K. The critical technologies for advanced systems were identified by reviewing the current state of the art of solar dynamic power systems. The experimental requirements were determined by planning a system test of a 20 kWe solar dynamic power system on the space station test facility. These

requirements were documented via the Mission Requirements Working Group (MRWG) and Technology Development Advocacy Group (TDAG) forms. Various concepts or considerations of advanced concepts are discussed. A preliminary evolutionary plan for this technology development mission was prepared. Author

**N87-15320*#** Wyle Labs., Inc., Huntsville, Ala.
**EQUIPMENT CONCEPT DESIGN AND DEVELOPMENT PLANS FOR MICROGRAVITY SCIENCE AND APPLICATIONS RESEARCH ON SPACE STATION: COMBUSTION TUNNEL, LASER DIAGNOSTIC SYSTEM, ADVANCED MODULAR FURNACE, INTEGRATED ELECTRONICS LABORATORY**
M. L. UHRAN, W. W. YOUNGBLOOD, T. GEORGEKUTTY, M. R. FISKE, and W. O. WEAR Sep. 1986 260 p
(Contract NAS3-24654)
(NASA-CR-179535; NAS 1.26:179535) Avail: NTIS HC A12/MF A01 CSCL 22A

Taking advantage of the microgravity environment of space NASA has initiated the preliminary design of a permanently manned space station that will support technological advances in process science and stimulate the development of new and improved materials having applications across the commercial spectrum. Previous studies have been performed to define from the researcher's perspective, the requirements for laboratory equipment to accommodate microgravity experiments on the space station. Functional requirements for the identified experimental apparatus and support equipment were determined. From these hardware requirements, several items were selected for concept designs and subsequent formulation of development plans. This report documents the concept designs and development plans for two items of experiment apparatus - the Combustion Tunnel and the Advanced Modular Furnace, and two items of support equipment the Laser Diagnostic System and the Integrated Electronics Laboratory. For each concept design, key technology developments were identified that are required to enable or enhance the development of the respective hardware. Author

**N87-15678*#** National Aeronautics and Space Administration, Washington, D.C.
**REFERENCE MISSION OPERATIONAL ANALYSIS DOCUMENT (RMOAD) FOR THE LIFE SCIENCES RESEARCH FACILITIES**
Jan. 1987 215 p
(NASA-TM-89604; NAS 1.15:89604) Avail: NTIS HC A10/MF A01 CSCL 06C

The space station will be constructed during the next decade as an orbiting, low-gravity, permanent facility. The facility will provide a multitude of research opportunities for many different users. The pressurized research laboratory will allow life scientists to study the effects of long-term exposure to microgravity on humans, animals, and plants. The results of these studies will increase our understanding of this foreign environment on basic life processes and ensure the safety of man's long-term presence in space. This document establishes initial operational requirements for the use of the Life Sciences Research Facility (LSRF) during its construction. Author

**N87-15995#** Naval Research Lab., Washington, D.C.
**THE SPACE STATION MICROWAVE FACILITY**
K. W. WEILER, B. K. DENNISON, R. M. BEVILACQUA, J. H. SPENCER, and K. J. JOHNSTON 19 Sep. 1986 78 p
(AD-A173964; NRL-MR-5821) Avail: NTIS HC A05/MF A01 CSCL 22B

A large millimeter wavelength interferometer array is proposed for construction on the planned space station (The Space Station Microwave Facility-SSMF). It will have manifold applications in both basic and applied research and will be the premier instrument in the world at high radio frequencies. All weather target detection and identification, Earth resource mapping, middle atmospheric studies, ionospheric research, atmospheric infrared background investigations, interplanetary communications, and high frequency radio astronomy are only a few of the areas which will be significantly advanced by the availability of such an instrument. Particularly in astronomy, the ability to do observations above the disturbing and absorbing effects of the Earth's atmosphere will allow new opportunities for exploration of all objects from the Sun, through the Solar System bodies, to the interstellar medium of the Milky Way and other galaxies, out to the most distant quasars with resolution and sensitivity equalling or exceeding all existing or planned millimeter wavelength telescopes. GRA

**N87-16030*#** Harris Corp., Palm Bay, Fla.
**DESCRIPTION OF THE MAST FLIGHT SYSTEM**
RONALD C. TALCOTT and JOHN W. SHIPLEY *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 253-263 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 22A

The Mast Flight System is composed of several subsystems. Primary among these is the Deployable Mast Subsystem (DMS) which consists of a beam assembly and an associated mechanism for deploying and retracting the beam. The beam assembly is a joint dominated graphite epoxy and titanium truss as is expected of future large space structures. Integral to the beam assembly are actuators, sensors and associated electronics which are available for excitation and damping as desired by the experimenter. The beam structural characteristics can also be modified as desired by the experimenter using the Parameter Modification Device installed at the end of the beam. Data measured on the beam by the sensors and commands to the actuators are transmitted along the beam digitally at 150 Hz using a standard 1553 type bus. The Modular Distributed Information Sybsystem (MDIS) computer functions as bus master and ensures that all experimental data is saved for future analysis. The MDIS computer also performs a safing function to prevent inadvertent overexcitation of the beam. Finally, the Excitation and Damping Subsystem (EDS) computer is available to the experimenter for implementation of control algorithms or any other numerical operations as desired. Data from all system sensors can be accessed by the EDS computer. Author

**N87-16031*#** Harris Corp., Palm Bay, Fla.
**MAST FLIGHT SYSTEM BEAM STRUCTURE AND BEAM STRUCTURAL PERFORMANCE**
DAVID C. LENZI and JOHN W. SHIPLEY *In* NASA. Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 265-279 Nov. 1986
Avail: NTIS HC A23/MF A01 CSCL 20K

An overall understanding of the beam assembly and data with which potential experimenters can begin to conduct analyses relevant to their experiments is given. Data is given on the beam structural concept, the tip remote station layout, the intermediate remote station layout with and without actuators, beam element materials, equivalent beam characteristics, beam element properties, remote station mass properties, and MAST Flight System modal characteristics. R.J.F.

**N87-16504*#** National Aeronautics and Space Administration, Washington, D.C.
**LIFE SCIENCES SPACE STATION PLANNING DOCUMENT: A REFERENCE PAYLOAD FOR THE EXOBIOLOGY RESEARCH FACILITIES**
Feb. 1987 62 p
(NASA-TM-89606; NAS 1.15:89606) Avail: NTIS HC A04/MF A01 CSCL 06B

The Cosmic Dust Collection and Gas Grain Simulation Facilities represent collaborative efforts between the Life Sciences and Solar System Exploration Divisions designed to strengthen a natural exobiology/Planetary Sciences connection. The Cosmic Dust Collection Facility is a Planetary Science facility, with Exobiology a primary user. Conversely, the Gas Grain Facility is an exobiology facility, with Planetary Science a primary user. Requirements for the construction and operation of the two facilities, contained herein, were developed through joint workshops between the two disciplines, as were representative experiments comprising the reference payloads. In the case of the Gas Grain Simulation Facility, the astrophysics Division is an additional potential user, having

participated in the workshop to select experiments and define requirements. Author

**N87-16755*#** Tennessee Univ., Martin. School of Engineering Technology and Engineering.
**AUTONOMOUSLY MANAGED ELECTRICAL POWER SYSTEMS**
CHARLES P. CALLIS *In* NASA. Marshall Space Flight Center Research Reports: 1986 NASA/ASEE Summer Faculty Fellowship Program 25 p Nov. 1986
Avail: NTIS HC A99/MF E04 CSCL 09C

The electric power systems for future spacecraft such as the Space Station will necessarily be more sophisticated and will exhibit more nearly autonomous operation than earlier spacecraft. These new power systems will be more reliable and flexible than their predecessors offering greater utility to the users. Automation approaches implemented on various power system breadboards are investigated. These breadboards include the Hubble Space Telescope power system test bed, the Common Module Power Management and Distribution system breadboard, the Autonomusly Managed Power System (AMPS) breadboard, and the 20 kilohertz power system breadboard. Particular attention is given to the AMPS breadboard. Future plans for these breadboards including the employment of artificial intelligence techniques are addressed. Author

**N87-16781*#** Tri-State Univ., Angola, Ind. Dept. of Mechanical and Aerospace Engineering.
**TETHER CRAWLER SYSTEM**
FRANK R. SWANSON *In* NASA. Marshall Space Flight Center Research Reports: 1986 NASA/ASEE Summer Faculty Fellowship Program 27 p Nov. 1986
Avail: NTIS HC A99/MF E04 CSCL 22B

A crawler system is designed to move a low-g/variable-g laboratory module along a tether between the Space Station and an attached space platform. An analysis is made of the effects of control law parameter change on the displacement, velocity, and acceleration of the crawler system. The control law is then modified by the addition of a constant-velocity section and the values of distance traveled, velocity, and acceleration are analyzed as a function of time. The power and torque equations are derived for a crawler system moving along a tether in orbit and numerical values of power and torque required for each prescribed movement are calculated versus time for four different cases using the control laws. A two-step control sequence is selected to permit initial location along the tether by distance traveled, followed by a vernier movement to reach the final desired constant net acceleration level. The components for the control system are identified and arranged in a block disgram configuration. The support subsystems are also identified. The sections were integrated to develop a procedure for the determination of crawler system performance requirements and the initial design of tether crawler systems. B.G.

**N87-16855*#** Martin Marietta Corp., Denver, Colo.
**TETHERED ORBITAL REFUELING STUDY Final Report**
DALE A. FESTER, L. KEVIN RUDOLPH, ERLINDA R. KIEFEL, PETER W. ABBOTT, and PAT GROSSRODE Apr. 1986 150 p
(Contract NAS9-17059; NAS9-17422)
(NASA-CR-171954; NAS 1.26:171954; MCR-86-587; MCR-86-591) Avail: NTIS HC A07/MF A01 CSCL 22A

One of the major applications of the space station will be to act as a refueling depot for cryogenic-fueled space-based orbital transfer vehicles (OTV), Earth-storable fueled orbit maneuvering vehicles, and refurbishable satellite spacecraft using hydrazine. One alternative for fuel storage at the space station is a tethered orbital refueling facility (TORF), separated from the space station by a sufficient distance to induce a gravity gradient force that settles the stored fuels. The technical feasibility was examined with the primary focus on the refueling of LO2/LH2 orbital transfer vehicles. Also examined was the tethered facility on the space station. It was compared to a zero-gravity facility. A tethered refueling facility should be considered as a viable alternative to a zero-gravity facility if the zero-gravity fluid transfer technology, such as the propellant management device and no vent fill, proves to be difficult to develop with the required performance. Author

**N87-16860*#** Research Triangle Inst., Research Triangle Park, N.C. Center for Systems Engineering.
**CONCEPT DEFINITION FOR SPACE STATION TECHNOLOGY DEVELOPMENT EXPERIMENTS. EXPERIMENT DEFINITION, TASK 2 Final Report**
Apr. 1986 285 p
(Contract NAS1-17639)
(NASA-CR-178153; NAS 1.26:178153; RTI/3042/07-01F) Avail: NTIS HC A13/MF A01 CSCL 22B

The second task of a study with the overall objective of providing a conceptual definition of the Technology Development Mission Experiments proposed by LaRC on space station is discussed. During this task, the information (goals, objectives, and experiment functional description) assembled on a previous task was translated into the actual experiment definition. Although still of a preliminary nature, aspects such as: environment, sensors, data acquisition, communications, handling, control telemetry requirements, crew activities, etc., were addressed. Sketches, diagrams, block diagrams, and timeline analyses of crew activities are included where appropriate. Author

**N87-16946#** Sener, S.A., Madrid (Spain).
**A SENER MECHANISM: FINE ADJUSTMENT MECHANISM FOR THE FAR INFRARED AND SUBMILLIMETER SPACE TELESCOPE (FIRST) (F F F)**
F. DELCAMPO, J. DELTORO, and J. RIVACOBA *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 205-210 Aug. 1986
Avail: NTIS HC A12/MF A01

A mechanism for obtaining very fine variations of the relative angular position of two surfaces having a common hinge axis is presented. The mechanism introduces no backlash, by using flexing elements for articulations. It can be designed for very high torsional stiffness. Applications include controlling the final angular aperture of deployable antennas, e.g., the petals of the FIRST antenna. For this case, main requirements are: minimum angular step 0.001 arc min; total angular range 2.6 arc min; torsional stiffness 900,000 Nm/rad. ESA

**N87-16956*#** Smithsonian Astrophysical Observatory, Cambridge, Mass.
**SYSTEM ENGINEERING STUDY OF ELECTRODYNAMIC TETHER AS A SPACEBORNE GENERATOR AND RADIATOR OF ELECTROMAGNETIC WAVES IN THE ULF/ELF FREQUENCY BAND Final Report**
ROBERT D. ESTES Feb. 1987 117 p
(Contract NAG8-551)
(NASA-CR-180156; NAS 1.26:180156) Avail: NTIS HC A06/MF A01 CSCL 20N

An electrodynamic tether deployed from a satellite in low-Earth orbit can perform, if properly instrumented, as a partially self-powered generator of electromagnetic waves in the ULF/ELF band, potentially at power levels high enough to be of practical use. Two basic problems are examined. The first is that of the level of wave power that the system can be expected to generate in the ULF/ELF radiation band. The second major question is whether an electrodynamic tethered satellite system for transmitting waves can be made partially self-powering so that power requirements for drag compensation can be met within economical constraints of mass, cost, and complexity. The theoretical developments and the system applications study are presented. The basic design criteria, the drag-compensation method, the effects on the propagation paths from orbit to Earth surface of high-altitude nuclear debris patches, and the estimate of masses and sizes are covered. An outline of recommended analytical work, to be performed as a follow-on to the present study, is contained. B.G.

**N87-16975#** Department of the Army, Washington, D. C.
**FREE ELECTRON DIODE OSCILLATOR Patent Application**
BRETT DAVID VANDESANDE, inventor (to Army) 19 Aug. 1986 18 p
(AD-D012519; US-PATENT-APPL-SN-897692) Avail: NTIS HC A02/MF A01 CSCL 09A

This invention relates to a crossed-field microwave power tube. Electrons are emitted from a tubular electrode at ground potential. The electrons are accelerated by an electric field toward a high voltage anode located within the tubular electrode. A magnetic field is oriented along the axis of the tube; the magnetic field is perpendicular to the electric field. The electrons follow curved paths in the space between the tubular electrode and the anode, while producing electromagnetic radiation in a transverse electromagnetic mode (TEM). The TEM radiation is easily coupled from the tube. GRA

**N87-17277#** Naval Research Lab., Washington, D.C. Space Systems and Technology Div.
**APPLICATION OF SPACEBORNE DISTRIBUTED APERTURE/COHERENT ARRAY PROCESSING (SDA/CAP) TECHNOLOGY TO ACTIVE AND PASSIVE MICROWAVE REMOTE SENSING**
M. S. KAPLAN *In* ESA Proceedings of the 1986 International Geoscience and Remote Sensing Symposium (IGARSS '86) on Remote Sensing: Today's Solutions for Tomorrow's Information Needs, Volume 1 p 697-701 Aug. 1986
Avail: NTIS HC A99/MF E03; ESA, Paris, France, 3 volume set $90 Member States, AU, CN, and NO (+20% others)

Application of spaceborne distributed aperture/coherent array processing (SDA/CAP) to environmental remote sensing missions is discussed. This technology differs from conventional monostatic remote sensing approaches in that sensor elements are distributed among many space platforms. It is possible to coherently combine the inputs from many receiving spacecraft in order to form a very large distributed aperture, thousands of kilometers in size. This enormous effective aperture size can provide nanoradian resolution in the microwave region of the spectrum. Relative spacecraft phase measurement accuracies on the order of a fraction of a wavelength are required to support the technology. Spacecraft relative position and time measurement via hydrogen maser time references on each spacecraft and laser ranging between spacecraft is proposed. Intersatellite laser ranging technology needs to be developed to support the application of SDA/CAP techniques for advanced space environmental remote sensor systems. ESA

**N87-17502*#** Smithsonian Astrophysical Observatory, Cambridge, Mass.
**INVESTIGATION OF PLASMA CONTACTORS FOR USE WITH ORBITING WIRES Semiannual Report, 1 Jan. - 30 Jun. 1986**
ROBERT D. ESTES Feb. 1987 33 p
(Contract NAG9-126)
(NASA-CR-180154; NAS 1.26:180154; SAR-1) Avail: NTIS HC A03/MF A01 CSCL 20I

The results of a number of orbital simulations for a 300km orbital height and 28 degrees orbital inclination are included to emphasize the importance of the choice of the timing of the experiments. The bulk of the effort has gone into trying to determine the shape, size, and other optical properties of the plasma clouds that will be emitted by the hollow cathodes. B.G.

**N87-17775*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**NEED FOR ARTIFICIAL GRAVITY ON A MANNED MARS MISSION?**
JOSEPH C. SHARP *In* NASA. Marshall Space Flight Center Manned Mars Mission. Working Group Papers, V. 2, Sect. 5, App. p 630-633 May 1986
Avail: NTIS HC A24/MF A01 CSCL 22A

Drawing upon the extensive Soviet and Skylab medical observations, the need for artificial gravity (g) on a manned Mars mission is discussed. Little hard data derived from well done experiments exist. This dearth of information is primarily due to two factors. Inability to collect tissues from astronauts for ethical or operational reasons. Second, there was not opportunities to fly animals in space to systematically evaluate the extent of the problem, and to develop and then to prove the effectiveness of countermeasures. The Skylab and space station will provide the opportunity to study these questions and validate suggested solutions. Author

**N87-17846#** Lawrence Livermore National Lab., Calif.
**PRELIMINARY FINDINGS FOR INTEGRATED MODELING AND SIMULATION OF DIRECTED ENERGY WEAPONS**
K. D. PIMENTEL, D. T. GAVEL, and J. W. ROBLEE 22 May 1986 8 p Presented at the 2nd European Simulation Congress, Antwerp, Belgium, 9 Sep. 1986
(Contract W-7405-ENG-48)
(DE86-011636; UCRL-93765; CONF-8609113-1) Avail: NTIS HC A02/MF A01

A preliminary study was recently completed at Lawrence Livermore National Laboratory of the issues important to the integrated modeling and simulation of future directed energy weapon (DEW) space platforms. The preliminary study comprised three parts: (1) a preliminary survey of existing computer codes used for integrated modeling and simulation; (2) work by a multidisciplinary team on a simple optical beam expander model to motivate cooperation in the three technical areas of space structures, optics, and control systems; and (3) identifying needs in integrated modeling and simulation for DEW systems. Results of this study indicate that much of the technology for end-to-end modeling and simulation of DEW space platforms may be in hand today. However, there may be critical needs in certain modeling and simulation areas, particularly in the package integration and computer/human interface areas, that are beyond the current state of the art to meet required levels of performance. DOE

**N87-18583*#** Science Applications International Corp., Schaumberg, Ill. Advanced Planning and Analysis Div.
**SATELLITE SERVICING PRICE ESTIMATION INSTRUCTION BOOKLET**
Jan. 1987 47 p
(Contract NAS9-17207)
(NASA-CR-171967; NAS 1.26:171967; SAIC-87/1515; SAIC-1-120-778-C15) Avail: NTIS HC A03/MF A01 CSCL 22A

The results of a brief study to develop a possible methodology for estimating the price to non-U.S. Government users for satellite servicing are documented. B.G.

**N87-18593*#** Martin Marietta Corp., Denver, Colo.
**STUDY OF SELECTED TETHER APPLICATIONS IN SPACE, PHASE 3, VOLUME 2 Final Report**
Sep. 1986 112 p
(Contract NAS8-36616)
(NASA-CR-178936-VOL-2; NAS 1.26:178936-VOL-2; MCR-86-1346-VOL-2; DPD-665-VOL-2; DR-04-VOL-2) Avail: NTIS HC A06/MF A01 CSCL 22B

The results of a Phase 3 study of two Selected Tether Applications in Space (STAIS); deorbit of a Shuttle and launch of an Orbital Transfer Vehicle (OTV), both from the space station using a tether were examined. The study objectives were to: perform a preliminary engineering design, define operational scenarios, develop a common cost model, perform cost benefits analyses, and develop a Work Breakdown Structure (WBS). Key features of the performance analysis were to identify the net increases in effective Shuttle cargo capability if tethers are used to assist in the deorbit of Shuttles and the launching of the OTVs from the space station and to define deployer system designs required to accomplish these tasks. Deployer concepts were designed and discussed. Operational scenarios, including timelines, for both tethered and nontethered Shuttle and OTV operations at the space station were evaluated. A summary discussion of the Selected Tether Applications Cost Model (STACOM) and the results of the cost benefits analysis are presented. Several critical technologies needed to implement tether assisted deployment of

payloads are also discussed. Conclusions and recommendations are presented. B.G.

**N87-18594*#** Martin Marietta Corp., Denver, Colo.
**STUDY OF SELECTED TETHER APPLICATIONS IN SPACE, PHASE 3, VOLUME 1 Executive summary**
Sep. 1986 26 p
(Contract NAS8-36616)
(NASA-CR-178935-VOL-1; NAS 1.26:178935-VOL-1; MCR-86-1346-VOL-1; DPD-665-VOL-1; DR-04-VOL-1) Avail: NTIS HC A03/MF A01 CSCL 22B

A dual keel space station configuration was used. The Mobility System, created for moving components over one face of the Space Station, makes it possible to use a single tether deployer system for both Orbit Transfer Vehicles (OTV) and Shuttle launches. Deployer concepts ranging from a minimum capability system that can deorbit the Shuttle from a maximum altitude of 370 km to a full capability system that can deploy the OTN with 9,072 kg of payload and using 150 km of tether were designed and discussed. Results of the cost benefits analyses are discussed. Conclusions and recommendations for implementing a specific design configuration and for future development and study activities are presented. B.G.

**N87-18821*#** National Aeronautics and Space Administration, Washington, D.C.
**TETHER DYNAMICS SIMULATION**
Feb. 1987 338 p Workshop held in Arlington, Va., 16 Sep. 1986
(NASA-CP-2458; NAS 1.55:2458) Avail: NTIS HC A15/MF A01 CSCL 22B

The proceedings of the conference are presented. The objective was to provide a forum for the discussion of the structure and status of existing computer programs which are used to simulate the dynamics of a variety of tether applications in space. A major topic was different simulation models and the process of validating them. Guidance on future work in these areas was obtained from a panel discussion; the panel was composed of resource and technical managers and dynamic analysts in the tether field. The conclusions of this panel are also presented.

**N87-18822*#** Lang (David D.) Associates, Mercer Island, Wash.
**GTOSS: GENERALIZED TETHERED OBJECT SIMULATION SYSTEM**
DAVID D. LANG *In* NASA, Washington Tether Dynamics Simulation p 73-94 Feb. 1987
Avail: NTIS HC A15/MF A01 CSCL 22B

GTOSS represents a tether analysis complex which is described by addressing its family of modules. TOSS is a portable software subsystem specifically designed to be introduced into the environment of any existing vehicle dynamics simulation to add the capability of simulating multiple interacting objects (via multiple tethers). These objects may interact with each other as well as with the vehicle into whose environment TOSS is introduced. GTOSS is a stand alone tethered system analysis program, representing an example of TOSS having been married to a host simulation. RTOSS is the Results Data Base (RDB) subsystem designed to archive TOSS simulation results for future display processing. DTOSS is a display post processors designed to utilize the RDB. DTOSS extracts data from the RDB for multi-page printed time history displays. CTOSS is similar to DTOSS, but is designed to create ASCII plot files. The same time history data formats provided for DTOSS (for printing) are available via CTOSS for plotting. How these and other modules interact with each other is discussed. Author

**N87-18824*#** Turin Univ. (Italy).
**RIGOROUS APPROACHES TO TETHER DYNAMICS IN DEPLOYMENT AND RETRIEVAL**
ETTORE ANTONA *In* NASA, Washington Tether Dynamics Simulation p 315-336 Feb. 1987
Avail: NTIS HC A15/MF A01 CSCL 22B

Dynamics of tethers in a linearized analysis can be considered as the superposition of propagating waves. This approach permits a new way for the analysis of tether behavior during deployment and retrieval, where a tether is composed by a part at rest and a part subjected to propagation phenomena, with the separating section depending on time. The dependence on time of the separating section requires the analysis of the reflection of the waves travelling toward the part at rest. Such a reflection generates a reflected wave, whose characteristics are determined. The propagation phenomena of major interest in a tether are transverse waves and longitudinal waves, all mathematically modelled by the vibrating chord equations, if the tension is considered constant along the tether. An interesting problem also considered is concerned with the dependence of the tether tension from the longitudinal position, due to microgravity, and the influence of this dependence on the propagation waves. Author

**N87-18907*#** California Univ., Santa Barbara. Information Sciences Research Group.
**REMOTE SENSING INFORMATION SCIENCES RESEARCH GROUP, YEAR FOUR**
JOHN E. ESTES, TERENCE SMITH, and JEFFREY L. STAR 1 Jan. 1987 140 p
(Contract NAGW-455)
(NASA-CR-180198; NAS 1.26:180198) Avail: NTIS HC A07/MF A01 CSCL 05B

The needs of the remote sensing research and application community which will be served by the Earth Observing System (EOS) and space station, including associated polar and co-orbiting platforms are examined. Research conducted was used to extend and expand existing remote sensing research activities in the areas of georeferenced information systems, machine assisted information extraction from image data, artificial intelligence, and vegetation analysis and modeling. Projects are discussed in detail. B.G.

**N87-19443*#** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
**ASTROMAG: A SUPERCONDUCTING PARTICLE ASTROPHYSICS MAGNET FACILITY FOR THE SPACE STATION**
M. A. GREEN (California Univ., Berkeley. Lawrence Berkeley Lab.), G. F. SMOOT, R. L. GOLDEN (New Mexico State Univ., Las Cruces), M. H. ISRAEL (Washington Univ., St. Louis, Mo.), R. KEPHART (Fermi National Accelerator Lab., Batavia, Ill.), R. NIEMANN, R. A. MEWALT (California Inst. of Tech., Pasadena), J. F. ORMES, P. SPILLANTINI (Florence Univ., Italy), and M. E. WIDENBECK (Chicago Univ., Ill.) Sep. 1986 8 p Presented at the Applied Superconductivity Conference (ASC '86), Baltimore, Md., 28 Sep. 1986
(Contract DE-AC03-76SF-00098)
(NASA-TM-89277; NAS 1.15:89277; DE87-002574; LBL-22343; CONF-860914-10) Avail: NTIS HC A02/MF A01 CSCL 22B

This paper describes a superconducting magnet system which is the heart of a particle astrophysics facility to be mounted on a portion of the proposed NASA space station. This facility will complete the studies done by the electromagnetic observatories now under development and construction by NASA. The paper outlines the selection process of the type of magnet to be used to analyze the energy and momentum of charged particles from deep space. The ASTROMAG superconducting magnet must meet all the criteria for a shuttle launch and landing, and it must meet safety standards for use in or near a manned environment such as the space station. The magnet facility must have a particle gathering aperture of at least 1 square meter steradian and the facility should be capable of resolving heavy nuclei with a total energy of 10 Tev or more. DOE

**N87-19814#** Societe Nationale Industrielle Aerospatiale, Cannes (France). Div. Systems Balistiques et Spatiaux.
**THE CONCENTRATION PRINCIPLE APPLIED TO SPACEBORNE SOLAR ARRAYS. APPLICATION TO THE COORBITING PLATFORM MISSION: STUDIES SYNTHESIS**
R. LAGET Paris, France ESA 27 Jan. 1986 46 p
(Contract ESA-5978/84-NC-PB(SC))
(SNIAS-975-CA/CG; ESA-CR(P)-2291-VOL-1; ETN-87-99482)
Avail: NTIS HC A03/MF A01

Studies that led to selection of the distributed concentration biplane concept for the solar cell generator to be flown on the coorbiting platform mission, and the major characteristics of such a spaceborne solar array are summarized. It is concluded that there is not a considerable interest in concentration either for array area reduction or cost reduction, although improvements of 15% for both domains are feasible. Only predevelopment activities to verify concentrator performances and system studies to assess respective importance of cost and area saving may increase the level of interest of concentrator solar arrays for this kind of mission. ESA

**N87-20057*#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.
**LARGE STRUCTURES AND TETHERS WORKING GROUP**
G. MURPHY, H. GARRETT, U. SAMIR, A. BARNETT, J. RAITT, J. SULLIVAN, and I. KATZ *In its* Space Technology Plasma Issues in 2001 p 6-11 1 Oct. 1986
Avail: NTIS HC A20/MF A01 CSCL 22B

The Large Structures and Tethers Working Group sought to clarify the meaning of large structures and tethers as they related to space systems. Large was assumed to mean that the characteristic length of the structure was greater than one of such relevant plasma characteristics as ion gyroradius or debey length. Typically, anything greater than or equal to the Shuttle dimensions was considered large. It was agreed that most large space systems that the tether could be better categorized as extended length, area, or volume structures. The key environmental interactions were then identified in terms of these three categories. In the following Working Group summary, these categories and the related interactions are defined in detail. The emphasis is on how increases in each of the three spatial dimensions uniquely determine the interactions with the near-Earth space environment. Interactions with the environments around the other planets and the solar wind were assumed to be similar or capable of being extrapolated from the near-Earth results. It should be remembered in the following that the effects on large systems do not just affect specific technologies but will quite likely impact whole missions. Finally, the possible effects of large systems on the plasma environment, although only briefly discussed, were felt to be of potentially great concern. Author

**N87-20068*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**SOLAR TERRESTRIAL AND PLASMA PROCESSES EXPERIMENTS ON SPACE STATION**
W. T. ROBERTS, J. L. KROPP (TRW, Inc., Redondo Beach, Calif.), W. W. L. TAYLOR, and S. D. SHAWHAN (National Aeronautics and Space Administration, Washington, D.C.) *In* JPL, Space Technology Plasma Issues in 2001 p 149-166 1 Oct. 1986
Avail: NTIS HC A20/MF A01 CSCL 20I

The currently planned utilization of the space station to perform investigations in solar terrestrial physics and plasma physics is outlined. The investigations and instrumentation planned for the Solar Terrestrial Observatory and its associated space station accommodation requirements are described. In addition, the planned placement of the Solar Terrestrial Observatory instruments are discussed along with typical operational scenarios. In the area of plasma physics, some preliminary plans for scientific investigations and for the accommodation of a plasma physics facility attached to the space station called the Plasma Processes Laboratory are outlined. These preliminary experiment concepts use the space environment around the space station as an unconfined plasma laboratory. Author

**N87-20071*#** Science Applications International Corp., McLean, Va. Plasma Physics Div.
**TECHNICAL ISSUES IN THE CONDUCT OF LARGE SPACE PLATFORM EXPERIMENTS IN PLASMA PHYSICS AND GEOPLASMA SCIENCES**
EDWARD P. SZUSZCZEWICZ *In* JPL, Space Technology Plasma Issues in 2001 p 225-236 1 Oct. 1986
Avail: NTIS HC A20/MF A01 CSCL 20I

Large, permanently-manned space platforms can provide exciting opportunities for discoveries in basic plasma and geoplasma sciences. The potential for these discoveries will depend very critically on the properties of the platform, its subsystems, and their abilities to fulfill a spectrum of scientific requirements. With this in mind, the planning of space station research initiatives and the development of attendant platform engineering should allow for the identification of critical science and technology issues that must be clarified far in advance of space station program implementation. An attempt is made to contribute to that process, with a perspective that looks to the development of the space station as a permanently-manned Spaceborne Ionospheric Weather Station. The development of this concept requires a synergism of science and technology which leads to several critical design issues. To explore the identification of these issues, the development of the concept of an Ionospheric Weather Station will necessarily touch upon a number of diverse areas. These areas are discussed. Author

**N87-20074*#** Massachusetts Inst. of Tech., Cambridge. Dept. of Aeronautics and Astronautics.
**PLASMA ISSUES ASSOCIATED WITH THE USE OF ELECTRODYNAMIC TETHERS**
D. E. HASTINGS *In* JPL, Space Technology Plasma Issues in 2001 p 263-275 1 Oct. 1986
Avail: NTIS HC A20/MF A01 CSCL 20I

The use of an electrodynamic tether to generate power or thrust on the space station raises important plasma issues associted with the current flow. In addition to the issue of current closure through the space station, high power tethers (equal to or greater than tens of kilowatts) require the use of plasma contactors to enhance the current flow. They will generate large amounts of electrostatic turbulence in the vicinity of the space station. This is because the contactors work best when a large amount of current driven turbulence is excited. Current work is reviewed and future directions suggested. Author

**N87-20076*#** Schafer (W. J.) Associates, Inc., Arlington, Va.
**HIGH CURRENT/HIGH POWER BEAM EXPERIMENTS FROM THE SPACE STATION**
HERBERT A. COHEN *In* JPL, Space Technology Plasma Issues in 2001 p 289-294 1 Oct. 1986
Avail: NTIS HC A20/MF A01 CSCL 18K

In this overview, on the possible uses of high power beams aboard the space station, the advantages of the space station as compared to previous space vehicles are considered along with the kind of intense beams that could be generated, the possible scientific uses of these beams and associated problems. This order was delibrately chosen to emphasize that the means, that is, the high power particle ejection devices, will lead towards the possible ends, scientific measurements in the Earth's upper atmosphere using large fluxes of energetic particles. Author

**N87-20078*#** Utah State Univ., Logan.
**LARGE MANNED SYSTEMS/ENVIRONMENT INTERACTIONS IN LOW EARTH ORBIT (LEO) Abstract Only**
W. J. RAITT *In* JPL, Space Technology Plasma Issues in 2001 p 309 1 Oct. 1986
Avail: NTIS HC A20/MF A01 CSCL 04A

With the advent of the NASA Space Transportation System, regular flights of a large manned spacecraft, the Space Shuttle Orbiter, became a reality. From the earliest mission containing space science instruments as a payload on the third flight of the Orbiter (STS-3), it became apparent that the disturbance caused by the interaction of this orbiting system with the low Earth orbit

(LEO) environment resulted in adverse conditions for the performance of scientific observations of the Orbiter natural environment and for certain high sensitivity optical observations. The interaction of the Space Shuttle Orbiter system can be divided into two parts, the structure-environment interaction, and the outgas cloud-environment interaction. These interaction are briefly discussed. Author

# 16

# OPERATIONS SUPPORT

Includes descriptions of models, analyses and trade studies of maneuvers, performance, Logistics support, and EVA and/or IVA servicing requirements of systems such as the OMV and OTV, and experiments.

**A87-10038**
**SATELLITE SERVICING - LOGISTICS SUPPORT**
J. E. ABEL (Lockheed Missiles and Space Co., Huntsville, AL) IN: Space Congress, 23rd, Cocoa Beach, FL, April 22-25, 1986, Proceedings . Cape Canaveral, FL, Canaveral Council of Technical Societies, 1986, p. 4-40 to 4-60.

This report addresses anticipated servicing requirements for orbital maintenance considering ground support operations, centralized depot concept, logistics module utilization/servicing/maintenance/integration and orbital docking and servicing. Anticipated costs to sustain orbital maintenance, servicing, and support of future free flyers and the space station leads to a conclusion that optimum support with reduced support costs can best be achieved by standardization and centralization of support facilities. The centralized depot concept and logistics module utilization described herein provides a scenario to achieve the supportability goals and reduce the overall satellite servicing cost. Author

**A87-10049**
**GAMMA RAY OBSERVATORY ON-ORBIT SERVICING**
D. A. MOLGAARD (TRW, Inc., Space and Technology Group, Redondo Beach, CA) IN: Space Congress, 23rd, Cocoa Beach, FL, April 22-25, 1986, Proceedings . Cape Canaveral, FL, Canaveral Council of Technical Societies, 1986, p. 8-23 to 8-36.

The feasibility of performing on-orbit servicing of the NASA Goddard Space Flight Center (GSFC) Gamma Ray Observatory (GRO) was initially addressed by TRW during the later portion of the Phase C development contract in 1981/82. The current post CDR GRO design reflects a capability for on-orbit changeout of the two Multimission Modular Spacecraft (MMS) modular power system (MPS) modules and the MMS communications and data handling (CADH) module via EVA. In addition, the design incorporates a capability for on-orbit refueling (OOR). The GRO design also incorporates a capability of EVA override operations for the deployment, restowage, and jettison of the GRO solar array and high-gain antenna appendages, the grapple fixture, and the electrical umbilical interface. To validate the GRO EVA design compatibility prior to CDR, a series of five separate astronaut-suited test runs were performed in the first quarter of 1985 at the NASA/JSC Weightless Environment Training Facility (WETF) using a high-fidelity full-scale mock-up (FSM) of the GRO. Author

**A87-10542**
**UPPER STAGES FOR A SPACE TRANSPORTATION SYSTEM**
O. P. HARWOOD British Interplanetary Society, Journal (Space Technology) (ISSN 0007-084X), vol. 39, Aug. 1986, p. 339-343.

Design features of a flexible use upper stage for the STS are described, noting that potential users must become interested if the system is to be developed. Based on the design for the low-energy Orbital Maneuvering Vehicle (OMV), the system would be required to utilize the Orbiter payload bay, have reattachable separation devices, have replaceable external propellant tanks, and have standard mechanical and functional interfaces. Implementation of an open grid triangular lattice structure covered with standardized aluminum plates would allow for the system to be tailored to specific missions at standardized increments of size. The system would tilt out of the bay and deploy all necessary appendages before ascent to GEO. A small bi-propellant engine is recommended as a prototype propulsion system to meet launch and mass constraints, particularly for GEO boosts. M.S.K.

**A87-11358*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**ORBITAL RESUPPLY OF LIQUID HELIUM**
P. KITTEL (NASA, Ames Research Center, Moffett Field, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 23, July-Aug. 1986, p. 391-396. NASA-supported research. Previously cited in issue 17, p. 2465, Accession no. A85-37617. refs

**A87-11366*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**THERMAL DESIGN OF AEROASSISTED ORBITAL TRANSFER VEHICLE HEAT SHIELDS FOR A CONICAL DRAG BRAKE**
W. C. PITTS (NASA, Ames Research Center, Moffett Field, CA) and M. S. MURBACH (Informatics General Corp., Palo Alto, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 23, July-Aug. 1986, p. 442-448. Previously cited in issue 17, p. 2464, Accession no. A85-38449. refs

**A87-12577*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**A REVIEW OF SHOCK WAVES AROUND AEROASSISTED ORBITAL TRANSFER VEHICLES**
C. PARK (NASA, Ames Research Center, Moffett Field, CA) IN: Shock waves and shock tubes; Proceedings of the Fifteenth International Symposium, Berkeley, CA, July 28-August 2, 1985 . Stanford, CA, Stanford University Press, 1986, p. 27-41. Previously announced in STAR as N85-33177. refs

Aeroassisted orbital transfer vehicles (AOTVs) are a proposed type of reusable spacecraft that would be used to transport cargoes from one earth-bound orbit to another. Such vehicles could be based on the proposed space station and used to transport commercial satellites from the space station to geostationary orbits or to polar orbits and return. During a mission, AOTVs would fly through earth's atmosphere, thus generating aerodynamic forces that could be used for decelerating the vehicles or changing their direction. AOTV research findings were concerned with the shock-wave-induced, high-temperature airflows that would be produced around these vehicles during atmospheric flight. Special emphasis was placed on the problems of: (1) the chemical physics of multitemperature, ionizing, nonequilibrium air flows, and (2) the dynamics of the flows in the base region of a blunt body with complex afterbody geometry. Author

**A87-13717*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**VISION REQUIREMENTS FOR SPACE STATION APPLICATIONS**
K. R. CROUSE (NASA, Johnson Space Center, Houston, TX) IN: Space station automation; Proceedings of the Meeting, Cambridge, MA, September 17, 18, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1985, p. 95-98.

Problems which will be encountered by computer vision systems in Space Station operations are discussed, along with solutions be examined at Johnson Space Station. Lighting cannot be controlled in space, nor can the random presence of reflective surfaces. Task-oriented capabilities are to include docking to moving objects, identification of unexpected objects during autonomous flights to different orbits, and diagnoses of damage and repair requirements for autonomous Space Station inspection robots. The approaches being examined to provide these and other capabilities are television IR sensors, advanced pattern recognition programs feeding on data from laser probes, laser radar for robot eyesight and arrays of SMART sensors for automated location and tracking of target objects. Attention is

also being given to liquid crystal light valves for optical processing of images for comparisons with on-board electronic libraries of images. M.S.K.

**A87-14056*#** Martin Marietta Corp., Denver, Colo.
**COMPARISON OF A TETHERED TO A ZERO-GRAVITY REFUELING FACILITY**
E. R. KIEFEL, L. K. RUDOLPH, and D. A. FESTER (Martin Marietta Corp., Denver, CO) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 19 p. refs
(Contract NAS9-17422)
The space-based orbital transfer vehicle will require a large cryogenic fuel storage facility at the Space Station. An alternative to fuel storage on-board the Space Station is on a tethered orbital refueling facility (TORF) which is separated from the Space Station by a sufficient distance to induce a gravity gradient to settle the propellants. Overall costs and benefits of a particular tethered facility design have been defined relative to a representative zero-gravity facility on the Space Station. Results indicate that the TORF hardware and operations costs are roughly 40 percent higher than the comparable zero-g facility costs. The cost difference is negligible when compared to the launch cost of the fuel over the facility 10-year lifetime. Author

**A87-15196**
**EQUIPMENT DESIGNS FOR SPACE STATION EVA EXAMINED**
Aerospace Engineering (ISSN 0736-2536), vol. 6, Aug. 1986, p. 11-14.
A survey of projected Space Station operational requirements has revealed that EVA is called for in 193 missions. A group of EVA suit requirements has been derived, and three generic EVA suit architectures, characterized as 'soft', 'hybrid' and 'hard', have been evaluated against these requirements. Study results indicate that the hard suit concept is the most promising of the three configurations. O.C.

**A87-15377*** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
**THE SPACE STATION PROGRAM**
N. W. HINNERS (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Space Station beyond IOC; Proceedings of the Thirty-second Annual International Conference, Los Angeles, CA, November 6, 7, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 11-17.
(AAS PAPER 85-451)
Cost constraints to a large degree control the functionality and form of the IOC of the Space Station. Planning of Station missions must be delayed to retain flexibility, a goal also served by modular development of the Station and by multi-use laboratory modules. Early emphasis on servicing other spacecraft is recommended, as is using available Shuttle flight time for R&D on Space Station technologies and operations. M.S.K.

**A87-15385*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**SUPPORTING PLANETARY MISSIONS - THE SPACE STATION ROLE**
D. P. BLANCHARD (NASA, Johnson Space Center, Houston, TX) IN: Space Station beyond IOC; Proceedings of the Thirty-second Annual International Conference, Los Angeles, CA, November 6, 7, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 101-104. refs
(AAS PAPER 85-475)
Spacecraft destined for interplanetary flight can be assembled, fueled, and tested near the Space Station, thus providing for spacecraft too large and/or massive for launch from earth on a single boost. The 28.5-deg-inclination orbit of the Station will, however, cause penalties for some missions. Another Station role is to recover sample returns from, e.g., Mars or a comet. M.S.K.

**A87-15407**
**MAINTAINABILITY TECHNOLOGY**
P. H. ZORGER (General Electric Co., Space Systems Div., Reston, VA) IN: 1986 Annual Reliability and Maintainability Symposium, Las Vegas, NV, January 28-30, 1986, Proceedings . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, p. 77-82. refs
A brief background and the current application status of maintainability technology are presented. The application of this technology to large systems is discussed, emphasizing some of the problems associated with the technology when applied to a space environment. Three deficiencies in the technology are discussed: the addition of a maintainability program task on testability to determine the 'time' to detect, locate, and isolate faults/failures; 'time' data sources their application and use, and a methodology to synthesize 'time' values; and the conversion of 'time' values for use in a space environment. The frame work for the discussion is a total and complete proposed maintainability program. Some additional and new tasks are suggested as needed additions to MIL-STD-470A and all tasks are defined for a complete and comprehensive maintainability program. Author

**A87-15805#**
**SATELLITE MOTION ANALYSIS VIA LASER REFLECTOR PATTERN PROCESSING FOR RENDEZ-VOUS AND DOCKING**
I. NAKATANI, T. TANAMACHI, and K. NINOMIYA (Tokyo, University, Japan) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 10 p. refs
(IAF PAPER 86-06)
A practical method for estimating the relative attitude and distance between a target satellite (TS) and a rendezvous satellite using laser reflectors together with a CCD camera is discussed. A new arrangement of the reflectors on the TS is proposed where the data size required to identify and locate reflector points on the image plane is quite small and the state equations of motion are remarkably simple because the proposed scheme makes it possible to separate the rotational motion from translational motion. Thus it is possible to estimate the motion of the TS in real time using the Kalman filter technique and an onboard computer. C.D.

**A87-15811#**
**CONTINUOUS PATH CONTROL OF SPACE MANIPULATORS MOUNTED ON OMV**
Y. UMETANI and K. YOSHIDA (Tokyo Institute of Technology, Meguro, Japan) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p. refs
(IAF PAPER 86-13)
The control scheme of a space manipulator installed on the Orbital Maneuvering Vehicle (OMV) is analyzed kinematically for the task of capturing a target in orbit. The control method is based on the Resolved Motion Rate Control concept of Whiteny (1969). The conventional Jacobian matrix method for ground-fixed manipulators is expanded to the case of a manipulator mounted on the OMV by using the momentum conservation relation and other geometrical relations. A new generalized Jacobian matrix is derived, and the method is verified by a simulation study. C.D.

**A87-15814#**
**HUBBLE SPACE TELESCOPE - DAWN OF THE ERA OF SERVICEABLE SPACECRAFT**
L. A. WICKMAN (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 5 p.
(IAF PAPER 86-20)
The Hubble Space Telescope, scheduled for launch in late 1988, is designed to include on-orbit servicing as an integral part of its operational plan. Here, the design philosophy of the Space Telescope and the lessons learned are explored insofar as they can be applied to the design of future serviceable spacecraft. In particular, attention is given to the use of orbital replaceable units, redundancy, environmental considerations, workspace accessibility, and standardization of the design of mechanical fasteners. V.L.

**A87-15818#**

**THE ESA/MBB UNFURLABLE MESH ANTENNA DEVELOPMENT FOR MOBILE SERVICES**

H. KELLERMEIER, H. VORBRUGG (MBB/ERNO, Ottobrunn, West Germany), K. PONTOPPIDAN (TICRA A/S, Copenhagen, Denmark), and D. C. G. EASTON (ESA, European Space Technology Centre, Noordwijk, Netherlands) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p. refs
(IAF PAPER 86-27)

The Offset Unfurlable Mesh Antenna (UMA) concept being developed at MBB for communication missions ranging from 850 MHz up to 12 GHz is reviewed with reference to the main stages of the program, its current status, the performance of the UMA concept, and technology demonstration. The design development of the Technology Demonstration Model indicates that this type of reflector can meet the objectives not only in relation to M-SAT requirements but also in relation to other missions. These include meeting the surface tolerance and mesh characteristics required to reduce more stringent side lobe damping requirements and frequency reuse (multibeam capability) for a 5-m C-band Intelsat application and an 8-m L-band multibeam application. V.L.

**A87-15821#**

**ENHANCED PERFORMANCE FOR THE MANNED MANEUVERING UNIT**

P. E. BINGHAM (Martin Marietta Corp., Denver, CO) IAF, International Astronautical Congress, 17th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p.
(IAF PAPER 86-30)

The Manned Maneuvering Unit (MMU), its physical features, the controls, and the propulsion and electrical systems are described, and the operational experience with the MMU on its last two flights (STS 41-C and STS 51-A) is discussed. The need for more propulsion capability, indicated by the astronauts who used the MMU, will be met by the Propellant Tank Kit (PTK) being currently developed. The results of development testing in the NASA/JSC Weightless Environment Test Facility are discussed. I.S.

**A87-15829*#** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.

**U.S. EXPERIENCE IN SATELLITE SERVICING AND LINKAGE TO THE SPACE STATION ERA**

R. K. BROWNING (NASA, Goddard Space Flight Center, Greenbelt, MD) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p.
(IAF PAPER 86-43)

A history of on-orbit servicing and repair is given with emphasis placed on the Solar Maximum Repair Mission. The experience gained thus far in on-orbit servicing and the design of the Space Station's servicing capabilities impose the following requirements on users: (1) satellites must have a standard grapple for capture and a standard berthing interface, (2) Space Station safety requirements must meet to preclude damage to the Space Station or injury to the EVA crew, (3) sensitive instruments will need to implement remotely controlled protective devices to prevent damage, and (4) satellite thermal systems must be designed to maintain survival temperatures during transfer from orbit to the Space Station servicing facility. K.K.

**A87-15834*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

**LOGISTICS RESUPPLY SCENARIO FOR THE SPACE STATION**

L. POWELL, R. M. HOODLESS, JR. (NASA, Marshall Space Flight Center, Huntsville, AL), and J. A. STEBBINS (Boeing Aerospace Co., Huntsville, AL) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p.
(IAF PAPER 86-49)

The paper addresses an approach to developing an integrated scenario definition, operations considerations and hardware concepts development cycle that will provide the most effective set of concepts meeting Space Station logistics criteria. Attention is given to logistics system requirements sources, design package team involvement, requirements analysis and development, scenario development and evaluation, and logistics elements configuration. It is noted that the surviving set of integrated scenarios provided hardware and support requirements with built in discipline compliance and operational sensitivity. K.K.

**A87-15851#**

**OMNISTAR - LONG LIFE, FLEXIBLE SPACE PLATFORM FOR REMOTE SENSING**

R. C. MAEHL (RCA, Astro-Electronics Div., Princeton, NJ) and E. MOWLE (Earth Observation Satellite Co., Lanham, MD) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p.
(IAF PAPER 86-75)

This paper discusses the development and configuration of the OMNISTAR spacecraft, the first of which is currently under construction for use on the Landsat 6 Program, the first of the U.S. commercial Landsat missions. The rationale for the serviceable spacecraft will be reviewed with special attention to the critical areas of future expansion to accommodate a mixture of different types of payloads with differing mission requirements and the pressing launch vehicle considerations in the current environment. How these factors impact the system design will be considered in the context of the current Landsat 6 development and the overall system configuration will be discussed. The OMNISTAR approach to expandability will be considered along with an analysis of how the OMNISTAR platform will be applicable to future combined remote sensing missions as well as the basic Landsat mission without major redesign for the future or significant overdesign for current requirements. Author

**A87-15871#**

**FACTORS INFLUENCING SELECTION OF SPACE TRANSPORTATION OPTIONS**

R. H. MILLER, D. G. STUART, and A. AZARBAYEJANI IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 27 p. refs
(IAF PAPER 86-108)

An evaluation is made of the economic feasibility of two concepts for the lofting of cargo into LEO, as will be required by the building of large Space-Station and satellite-power-system structures. One of the alternatives considered is a fully reusable horizontal-takeoff-and-landing aircraft whose first stage is airbreathing and manned, while the second is rocket-powered and unmanned; the second alternative is fully expendable, with vertical takeoff, two rocket stages, and no crew or reentry provisions. It is found that costs are critically dependent on the assumed future traffic demand as well as on the choice of vehicle payload capability. O.C.

**A87-15875#**

**OTV BASING SENSITIVITY TO MISSION MODEL AND LAUNCH SYSTEM**

E. E. DAVIS and C. L. WILKINSON (Boeing Aerospace Co., Seattle, WA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p.
(IAF PAPER 86-112)

An analysis has been performed considering alternative OTV basing modes and the sensitivity of these modes to variations in the assumed mission models and launch systems. The principal criterion for concept selection was discounted life cycle cost. Phase I of the study involved a mission model with 145 OTV flights and the STS (Space Transportation System) as the launch system. The result was a reusable ground based mode offering a 15 and 2 percent cost advantage over a space based mode and combination ground plus space based mode, respectively. Phase II considered a larger model with 442 OTV flights and advanced launch systems (150 klbm unmanned cargo launcher and STS II). An expendable mode was considered in this analysis and was found to give a 28 percent cost advantage over reusable ground or space based modes primarily due to large savings in launch and earth return cost. Author

**A87-15878#**
**THE DIVERSITY OF ROLES FOR ORBITAL TRANSFER SYSTEMS**
P. H. BIALLA (General Dynamics Corp., Space Systems Div., San Diego, CA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p.
(IAF PAPER 86-116)

This paper focuses on the applicability of a space-based OTV to a variety of advanced missions and for alternative OTV basing concepts. The missions of interest, other than earth-orbital, include lunar and interplanetary orbiters and landers. An important conclusion of the paper is that one OTV design approach, based upon modularity, can accommodate the full mission spectrum. It is demonstrated that separation of the OTV accommodations system from the Space Station is desirable for safety, contamination, and microgravity reasons; this leads to a coorbiting platform dedicated to OTV basing, propellant storage, and payload integration. An OTV facility can also be operated in lunar orbit where it becomes a key transportation node for manned Mars exploration and development. Author

**A87-15879#**
**UNMANNED ORBIT TRANSFER VEHICLE DESIGN FOR RELIABILITY**
J. H. KEENEY (Boeing Aerospace Co., Seattle, WA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p.
(IAF PAPER 86-118)

This paper traces the reliability history of the design, development, and test of the IUS (Inertial Upper Stage) which is an unmanned orbit transfer vehicle. The IUS vehicle was developed for both USAF and NASA missions to carry spacecraft from low earth orbits to higher energy orbits. The design challenge for the IUS program was to maximize mission reliability to the point that further improvement was no longer cost effective. A summary of the reliability approach used in the development of the IUS along with the results of the first ten years of that endeavor is covered in four topics: (1) IUS Fault Tolerant design, (2) Reliability/cost optimization, (3) Test program effectiveness, and (4) Results to date. Author

**A87-15885#**
**LOW-COST LAUNCH SYSTEM AND ORBITAL FUEL DEPOT**
J. PEARSON (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. refs
(IAF PAPER 86-128)

A new system is proposed for the low-cost launching of large quantities of rocket fuel into earth orbit, storage in the orbit, and transfer of the fuel to the NASA Space Station. The system consists of an electromagnetic launcher which fires heat-shielded fuel tanks into high earth orbit, where they are captured by a long, rotating tether. The tether is in an elliptical orbit that ranges from high earth orbit down to low earth orbit, where it drops the fuel tanks into an orbit near the Space Station. The payloads are used for upper stage rockets, for stationkeeping propulsion, and for high-g-tolerant supplies for the Space Station. The system has the potential for launching more than 100,000 kg into earth orbit each year at a launch cost of less than $10/kg. Author

**A87-15889#**
**CHALLENGES FOR SPACE STATION LOGISTICS TRANSPORTATION**
W. BOLLENDONK (Martin Marietta Corp., Denver, CO) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 14 p.
(IAF PAPER 86-133)

An evaluation is made of the relationship between the Space Shuttle payload capability and launch frequency to the projected NASA Space Station resupply requirements. The present analysis reveals the need to maintain maximum hardware flexibility for a variety of cargos while simultaneously minimizing early cost investments through the limiting of hardware types and quantities. Early recognition of the need to limit multiple handling of such items as spares and support equipment has led to a reconsideration of orbital storage and disposal; the return of certain items is prohibitively costly. O.C.

**A87-15892#**
**VERY LOW TEMPERATURE RISE LASER ANNEALING OF THE RADIATION DAMAGED SOLAR CELLS IN-ORBIT**
V. POULEK (Ceskoslovenska Akademie Ved, Fyzikalni Ustav, Prague, Czechoslovakia) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 6 p. refs
(IAF PAPER 86-141)

Solar cells of all space objects are damaged by radiation in-orbit. This damage, however, can be removed by laser annealing. A new in-orbit laser regeneration system for both body and spin stabilized space objects is proposed. For successful annealing of solar cells damaged by a 10-year radiation dose in-orbit, it is necessary for the temperature rise in the incidence point of the laser beam to reach about 400 C. By continuous regeneration, however, between two annealing cycles the solar cells are hit by a two-order-of-magnitude lower radiation dose. This makes it possible to carry out the regeneration at temperature risė deep under 1 C. If the optimal laser regeneration system is used, such low temperature rise laser annealing of the radiation damaged solar cells is possible. A semiconductor GaAlAs diode laser with an output power up to 10 mW CW was used for annealing. Author

**A87-16082#**
**ORBITAL TRANSFER VEHICLE OPERATIONS FOR ORBITAL DEBRIS HAZARD MITIGATION**
M. W. HENLEY (General Dynamics Corp., Space Systems Div., San Diego, CA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 13 p. refs
(IAF PAPER 86-422)

Orbital debris is a serious problem of international proportions, which is expected to increase in LEO, and which may become a substantial hazard to GEO satellites. The Orbital Transfer Vehicle planned by NASA can assist in the solution of this problem by replacing the expendable upper stages now left in orbit, reducing the risk of upper stage explosions, and enabling satellite repair and refueling at GEO. The OTV also has the potential for active collection, retrieval, or de-orbit of existing debris objects. While the OTV may play a significant role in debris hazard mitigation, an increasing emphasis on this issue is needed from all of the users of near-earth space. Author

**A87-16112#**
**EVOLUTION OF SERVICING OF ORBITAL AND EXPEDITIONARY SYSTEMS**
W. L. SMITH (TRW, Inc., Federal Systems Div., Redondo Beach, CA) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 6 p.
(IAF PAPER 86-463)

This paper discusses the evolution of the alternatives of servicing future orbital and expeditionary space systems. It outlines new operational regimes which will offer a full spectrum of servicing for cost-effective support. Three evolutionary futures are explored: nominal evolutionary, high technology/high risk, and step function evolution. Some specific servicing systems concepts are highlighted in the context of the three alternative future pathways. The concepts are based on the solid foundation established by the accomlishments of the Space Transportation System and the projected mid-1990s operation of the International Space Station Complex. The summary of this paper integrates major issues which future planners and system designers will need to address. Author

**A87-16114*#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.
**ELEMENTS OF A MARS TRANSPORTATION SYSTEM**
K. T. NOCK (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) and A. L. FRIEDLANDER (Science Applications International Corp., Schaumburg, IL) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 24 p. NASA-supported research. refs
(IAF PAPER 86-466)

Earth to Mars transportation requirements are derived for a permanent Mars base of 20 people operating in the 2035 time frame. In order to satisfy these requirements, various transportation modes are developed assuming an existing space infrastructure including propellant tankers, crew and consumable transfer vehicles, orbital facilities and extraterrestrial propellant factories. These transportation modes are compared with respect to total propellant requirements, number of vehicles required, flight times, frequency of opportunity and several other characteristics. Directions for further studies and analysis are indicated. Author

**A87-16135#**
**LOGISTICS SUPPORT OF LUNAR BASES**
G. R. WOODCOCK (Boeing Aerospace Co., Huntsville, AL) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 21 p. refs
(IAF PAPER 86-511)

Concepts for lunar base design and operations have been studied for over twenty years. A brief summary of past concepts is presented, with reference to new ideas on design, uses and logistics schemes. Transportation systems and mission modes are reviewed, showing the significant cost benefits of reusable transportation at the higher traffic rates representative of lunar base buildup and logistics operations. Parametric studies are presented over the range of base size from 6 crew to 1000 crew, and the 'choke points', or barriers to growth are identified and means for their resolution presented. The leverages of food growth on the moon, crew stay time, use of lunar oxygen, indigenous resources for construction of facilities, and transportation systems size and operations modes are presented. It is concluded that bases as large as 1000 people are affordable at less than twice the cost of an initial base of six people if these leverages of advanced basing technologies are exploited. Author

**A87-16943**
**UTILITY REQUIREMENTS FOR SERVICEABLE PLATFORMS**
S. PALOCZ (RCA, Astro-Electronics Div., Princeton, NJ) Earth-Oriented Applications of Space Technology (ISSN 0277-4488), vol. 6, no. 3, 1986, p. 263-275.

'Utilities' in this report mean resources supplied to payload customers on the coorbiting and polar platforms associated with the Space Station Program. In particular, the following utilities are considered as resources/services to payload customers: power utility, thermal utility, pointing and structural accommodation resources, communication bandwidth and data timelines resources, data processing resources, servicing, repair and retrieval resources. Common requirements suggest a design aproach to 'utility platforms'. The ultimate goal is to design a family of commercially viable platforms with potential savings due to commonality and standardization, which would also serve NASA's Space Station 'design to cost' program goals. A utility pricing policy is suggested that could be an incentive for conserving scarce resources to commercial and scientific customers alike. Author

**A87-17146#**
**HOPE FOR SIMULATING FLEXIBLE SPACECRAFT**
R. GLUCK (TRW, Inc., Space and Technology Group, Redondo Beach, CA) Aerospace America (ISSN 0740-722X), vol. 24, Nov. 1986, p. 40-44.

The application of a custom architectured parallel processing system (CAPPS) to the simulation of a large angle maneuver of the Space Shuttle's remote manipulator system and power extension package, and to the despinning of a whirling flexible beam by torques are described. The CAPPS is fully digital and utilizes a large number of high-speed computational units (CUs); the design and operation of the system's CUs are examined. The system software consists of programs for: (1) deriving the equations of motion, (2) converting the equations to machine language for execution, and (3) of special algorithms for efficient parallel processing. Potential applications for CAPPS are discussed. I.F.

**A87-17401**
**ENGINEERING CONSIDERATIONS FOR ON-ORBIT WELDING OPERATIONS**
J. K. WATSON (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 34, Apr.-June 1986, p. 121-132. refs

The capability to perform on-orbit fabrication, maintenance, and repair will become increasingly necessary with the deployment of large, complex space systems in the 1990s and beyond. Just as it is indispensible for such operations on earth, welding will be an important technology in space. This paper describes a number of welding processes that may be applicable, discusses requirements for automation, and considers the supporting technologies required for successful welding operations. Author

**A87-17834*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**PATH-CONSTRAINED RENDEZVOUS - NECESSARY AND SUFFICIENT CONDITIONS**
K. M. SOILEAU (NASA, Johnson Space Center, Houston, TX) and S. A. STERN (Colorado, University, Boulder) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 23, Sept.-Oct. 1986, p. 492-498. refs

The problem of path-constrained rendezvous in the vicinity of a Large Space Structure (LSS) was first introduced some years ago. The present contribution to this field centers on a demonstration that the problem can be reduced from a path-constraint problem to one of end-point constraints or certain (common) LSS geometries, under the assumption of an unrestrictive upper limit on the transfer time. This finding has been made under the assumption of a circular Keplerian orbit, and has been normalized with respect to orbital semimajor axis and LSS size. In addition to demonstrating this important simplification of the path-constrained rendezvous problem, the results of numerical simulations of path-constrained transfers from point-to-point on large spherical structures in orbit are discussed, and a series of conclusions having both architectural (design) and operational implications for LSS designers/operators is derived. Author

**A87-18148**
**SPACE STATION CHALLENGE - ON-ORBIT ASSEMBLY OF A 75-KW POWER SYSTEM**
A. GLINES (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1892-1897. refs

Designing the NASA Space Station (SS) presents formidable challenges in all onboard systems. An excellent example is the electrical power system (EPS), one of the largest systems on the station and the first to be assembled. This paper focuses on those features of the SS EPS and its associated transverse truss which facilitate on-orbit assembly, servicing, and maintenance by astronauts during extra-vehicular activity (EVA). It reviews NASA's EPS assembly guidelines and design requirements, particularly those relating to EVA. The paper concludes with a discussion of EVA design verification using astronauts working on full-scale equipment mock-ups in NASA's neutral buoyancy facilities. Author

**A87-18344*** Martin Marietta Aerospace, Denver, Colo.
**ON-ORBIT CRYOGENIC STORAGE AND RESUPPLY**
R. N. EBERHARDT, J. P. GILLE, and D. A. FESTER (Martin Marietta Co., Denver, CO) IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 1113-1124.
(Contract NAS3-23355)

Methods of integrating pressure control, liquid acquisition, and liquid transfer concepts for the Cryogenic Fluid Management Facility, a reusable test bed in the Shuttle cargo bay studying the efficient management of cryogens in space, are investigated. Significant design data and criteria for future subcritical cryogenic storage and transfer systems are presented. Technology requirements for liquid storage/supply systems, thermal control systems, and fluid transfer/resupply are addressed, and fluid and thermal analysis pertaining to receiver tank chilldown and no-vent fill of the receiver tank are discussed. C.D.

**A87-18400**
**EMU - A HUMAN SPACECRAFT**
R. C. WILDE (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 1565-1576. refs

The Shuttle Extravehicular Mobility Unit (EMU), with propulsion from the Manned Maneuvering Unit, is the world's smallest manned spacecraft. This paper describes EMU capabilities and underlying human operator considerations, including bends prevention, suit sizing and task training, and highlights trends in future developments of manned extravehicular activity support systems. The EMU supports useful work in space by Space Shuttle astronauts working in the payload bay or floating nearby, untethered. The EMU provides its human occupant with a habitable environment, life support and communications, and is compatible with a variety of space tools and work aids. Author

**A87-18482**
**MODEL BASED VISION SYSTEM FOR AUTONOMOUS TELEOPERATED SPACECRAFT**
T. TANABE (Tokyo, University, Japan), H. KOYAMA, and E. OHYAMA IN: Space exploitation and utilization; Proceedings of the Symposium, Honolulu, HI, December 15-19, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 495-516. refs
(AAS PAPER 86-661)

A model based vision system which can extract the relative translational (position and velocity) and rotational (attitude and angular rate) information on the target spacecraft is presented. This system utilizes only image innformation obtained from a mounted imaging sensor. By taking advantage of a priori stored knowledge of the target spacecraft, the system can obtain relative translational and rotational information. Computer simulation and basic laboratory experiment results are also included. Discussion on the possibility of the target spacecraft identification is also given. Author

**A87-20682**
**SPACE REMOTE SENSING**
JOHN MCELROY (Earth Observation Satellite Co., New York) Spaceflight (ISSN 0038-6340), vol. 28, Sept.-Oct. 1986, p. 358-360.

A review of the U.S. Land Remote Sensing Programme (Landsat) from the Launch of ERTS in 1972 through the program's transfer to the private sector in 1985 is presented. The spacecraft design chosen by EOSAT for the future Landsats 6 and 7 is the OMNISTAR long life platform which will provide flexible design for Shuttle launch, retrieval and in-orbit refurbishment and component replacements. The platform contains instruments and subsystems designed for a minimum of five years in-orbit life. Applications include bathymetry, meteorology, and oceanography. R.R.

**A87-20994*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**A FLIGHT TEST CHALLENGE - AEROASSIST FOR REUSEABLE, SPACE-BASED TRANSPORTATION**
ROBERT C. RIED (NASA, Johnson Space Center, Houston, TX) Journal of Environmental Sciences (ISSN 0022-0906), vol. 29, Sept.-Oct. 1986, p. 26-31. refs

Attention is given to the challenges addressed by NASA in the development of reusable, space-based transportation systems which take advantage of aerobraking to achieve greater performance and overall efficiency. Aerobraking environmental factors associated with achieving higher energy reusable systems are outlined and the need for a coupled utilization of ground test capabilities and computational fluid dynamics (CFD) is demonstrated. It is concluded that the certification of CFD capability to provide the aerodynamic performance and aerothermodynamic environment for an aerobraking orbital transfer vehicle would be of major significance for the design and development of future flight systems. K.K.

**A87-21257#**
**SPACE STATION THRILLERS UNFOLD AT DRAPER LAB**
DON EYLES (Charles Stark Draper Laboratory, Inc., Cambridge, MA) Aerospace America (ISSN 0740-722X), vol. 24, Oct. 1986, p. 38-41.

The operational capabilities of a computer-graphics system designed for aiding operations in space (e.g., the recovery of a troubled spacecraft) are described. The visualization system will let the astronaut place his eye at any point of space and simulate space operations. The system will first create a dynamic scene based on the vectors and transformations that specify the real-world interrelationships between spacecraft and other objects. It then allows a number of points of view to be chosen within the overall scene. I.S.

**A87-21282**
**FLYING FREE**
KEITH WILSON Spaceflight (ISSN 0038-6340), vol. 28, Feb. 1986, p. 74, 75.

The development of the manned maneuvering unit (MMU) is examined. The initial testing of vrious MMU designs on Gemini and Skylab missions is discussed. The design, propulsion system, control electronics, thermal control, and operation of the MMU are described. The MMU is applicable to orbiter inspection, satellite servicing and repair, cargo transfer, scientific investigations and observations, and in-space construction and rescue operations, and two examples showing the use of the MMU are presented. I.F.

**A87-21502#**
**A MODULAR, ION PROPELLED, ORBIT TRANSFER VEHICLE**
J. HERMEL, R. A. MEESE, W. P. ROGERS, R. O. KUSHIDA (Hughes Aircraft Co., Los Angeles, CA), J. R. BEATTIE (Hughes Research Laboratories, Malibu, CA) et al. AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 22nd, Huntsville, AL, June 16-18, 1986. 10 p. refs
(AIAA PAPER 86-1394)

The design approach is presented for a modular, ion-propelled orbit transfer vehicle (OTV). The OTV consists of a propulsion module that can be returned to earth via the Shuttle for refueling and refurbishment, and a reusable power bus that mates to the spacecraft payload and remains in orbit. The technologies are identified that are required to make the OTV concept both technically and economically feasible. The OTV approach is shown to be particularly attractive, from a cost standpoint, for the specific application to GPS. The high specific impulse provided by ion propulsion is shown to result in a net reduction of $145 to $195 in overall cost for the GPS Block 3 mission as compared with the cost using the Payload Assist Module (PAM) D-II chemical propulsion stage. This reusable OTV approach is believed to be equally attractive for other missions that require multiple launches. Author

**A87-21804*** Los Alamos National Lab., N. Mex.
**SETTLEMENT OF THE MOON AND VENTURES BEYOND**
PAUL W. KEATON (Los Alamos National Laboratory, NM) IN: Space nuclear power systems 1985; Proceedings of the Second Symposium, Albuquerque, NM, Jan. 14-16, 1985. Volume 3 . Malabar, FL, Orbit Book Co., Inc., 1987, p. 27-32. NASA-sponsored research. refs

The formation of a permanent base on the moon following the establishment of the Space Station is proposed. The characteristics of the moon which make it advantageous for exploration and as a base are described. Consideration is given to lunar resources, the solar flare problem, and the cost of developing a moon base. I.F.

**A87-22364*#** Flight Mechanics and Control, Inc., Hampton, Va.
**DYNAMIC ANALYSIS OF SATELLITES WITH DEPLOYABLE HINGED APPENDAGES**
KEVIN F. OAKES (Flight Mechanics and Control, Inc., Hampton, VA) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 13 p. Research sponsored by Old Dominion University. refs
(Contract NGR-47-003-052)
(AIAA PAPER 87-0020)

The nonlinear equations of motion determining the planar dynamical behavior of an orbiting satellite deploying both one and two rigid appendages have been formulated using Lagrange's equations. The analysis accounts for large angle rotations, Coriolis effects, and the gravitational gradient, and the resulting coupled governing equations are integrated numerically. The analysis is applied to the Space Shuttle based deployment of rigid truss-like members, and results show that spacecraft inertia parameters, appendage mass and length, deployment velocity, and initial conditions all influence the system response. It is found that the resulting librational movement is related to the size of the deployment payload, and that gravitational forces lead to vehicle stabilization. R.R.

**A87-22460#**
**REDUCING THE COST AND RISK OF ORBIT TRANSFER**
JAMES R. WERTZ, THOMAS L. MULLIKIN (Ithaco/Microcosm, Inc., Torrance, CA), and ROBERT F. BRODSKY (TRW, Inc., Redondo Beach, CA) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 9 p. refs
(AIAA PAPER 87-0172)

Use of an autonomous, earth-referenced low thrust system for geosynchronous transfer or similar high energy orbit transfer maneuvers can dramatically reduce costs and improve reliability over the use of independent high thrust upper stages. Major cost savings are achieved by eliminating the duplication of components and subsystems between the spacecraft and upper stage. Eliminating components also reduces weight and increases reliability, or alternatively allows for additional on-orbit propellant or equipment. Low thrust transfer allows near-earth deployment and check-out so that malfunctioning spacecraft can be retrieved or repaired. It provides a more benign transfer to the operational orbit form which retrieval is not normally possible. It also allows greater operational flexibility for storage in low earth orbit following check-out or use of various orbits during different mission phases. Full autonomy during the critical sequence of perigee burns reduces both the cost and risk of ground operations. Finally, risk is further reduced by a fail-safe approach to orbit transfer which has fewer and less catastrophic failure modes than high thrust inertially guided systems. Author

**A87-22676#**
**IMPACT OF CREW WORKLOAD ON SPACE STATION ON-ORBIT OPERATIONS**
ANTHONY C. BEARDSLEY and ROBERT H. SCHAEFER (Grumman Aerospace Corp., Space Systems Div., Bethpage, NY) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 8 p. refs
(AIAA PAPER 87-0505)

The complexity of the Space Station coupled with the diversity of its operations charter places an enormous burden on the psychological and physiological domains of each flight crewmember. This condition is exacerbated by the hazards of the environment and the remoteness and isolation of the crewmembers over extended periods in space. Also, economics demand that each crewmember's time be optimized for maximum productivity in order to render the Space Station profitable and self-sustaining over time. Information on long-term exposure to man in space is sparse, but earlier spaceflights demonstrated that astronaut workloads were very high and that this contributed significantly to stress. The elements that make up workload and the methodologies of quantifying it are discussed. Also, the physiological and psychological factors that contribute to workload on orbit and their consequences on stress are examined. The impact of other variables such as schedules and how they add to workload and to overall stress on Space Station crewmembers is discussed. Author

**A87-22679*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**A SURVEY OF AEROBRAKING ORBITAL TRANSFER VEHICLE DESIGN CONCEPTS**
CHUL PARK (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 20 p. refs
(AIAA PAPER 87-0514)

The five existing design concepts of the aerobraking orbital transfer vehicle (namely, the raked sphere-cone designs, conical lifting-brake, raked elliptic-cone, lifting-body, and ballute) are reviewed and critiqued. Historical backgrounds, and the geometrical, aerothermal, and operational features of these designs are reviewed first. Then, the technological requirements for the vehicle (namely, navigation, aerodynamic stability and control, afterbody flow impingement, nonequilibrium radiation, convective heat-transfer rates, mission abort and multiple atmospheric passes, transportation and construction, and the payload-to-vehicle weight requirements) are delineated by summarizing the recent advancements made on these issues. Each of the five designs are critiqued and rated on these issues. The highest and the lowest ratings are given to the raked sphere-cone and the ballute design, respectively. Author

**A87-23239*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**STATUS OF ADVANCED PROPULSION FOR SPACE BASED ORBITAL TRANSFER VEHICLE**
LARRY P. COOPER and DEAN D. SCHEER (NASA, Lewis Research Center, Cleveland, OH) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 31 p. Previously announced in STAR as N87-10959. refs
(IAF PAPER 86-183)

A new Orbital Transfer Vehicle (OTV) propulsion system will be required to meet the needs of space missions beyond the mid-1990's. As envisioned, the advanced OTV will be used in conjunction with earth-to-orbit vehicles, Space Station, and Orbit Maneuvering Vehicle. The OTV will transfer men, large space structures, and conventional payloads between low earth and higher energy orbits. Space probes carried by the OTV will continue the exploration of the solar system. When lunar bases are established, the OTV will be their transportation link to earth. NASA is currently funding the development of technology for advanced propulsion concepts for future Orbital Transfer Vehicles. Progress in key areas during 1986 is presented. Author

**A87-23240#**
**OTV AEROASSIST WITH LOW L/D**
W. H. WILLCOCKSON (Martin Marietta Corp., Denver, CO) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 35 p. refs
(IAF PAPER 86-115)

In an attempt to make the OTV efficient and cost-effective, consideration is given to the aerobraking portion of the mission. It is proposed that the best method for controlling the trajectory in this phase is through the use of a lifting brake. Entry error analysis is used to derive an L/D requirement of 0.12; in addition, a predictor-corrector guidance scheme is developed to control exit apogee and orbital plane geometry in the aeroassist. The guidance includes density feedback functions to compensate for the large atmospheric fluctuations observed in Shuttle entries. K.K.

**A87-23255#**
**FLUID MANAGEMENT ON THE SPACE STATION**
SAM M. DOMINICK (Martin Marietta Corp., Denver, CO) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 22nd, Huntsville, AL, June 16-18, 1986. 11 p.
(AIAA PAPER 86-1565)

The NASA Space Station will require systems to store, transfer, and resupply fluid consumables needed by the various Space Station elements. Preliminary definitions of these systems have been completed. The systems include the fluid resupply pallets of the Logistics Module, the Manufacturing Technology Laboratory process fluids system, the Orbital Maneuvering Vehicle and Orbit Transfer Vehicle tank farms, the integrated nitrogen distribution system, the satellite servicing facility, and the fluid servicer kit for in-situ fluid resupply of spacecraft. These systems must store, resupply, and distribute fluids ranging from high pressure gases to cryogenics. Integration of the fluid systems has been shown to provide major cost savings in these systems and integrated systems are currently being defined as part of the preliminary design effort. The integrated nitrogen distribution system has been baselined for the initial Space Station. New fluid management technology development is required including space qualified compressors, mass gaging, and leak detection equipment. Author

**A87-24975*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
**SERVICING OPERATIONS FOR THE SIRTF OBSERVATORY AT THE SPACE STATION**
CHRISTOPHER B. WILTSEE and LARRY A. MANNING (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 12 p. refs
(AIAA PAPER 87-0504)

This paper describes the servicing requirements, plans, and proposed Space Station-based servicing operations for the Space Infrared Telescope Facility (SIRTF) Observatory. SIRTF is a cryogenically-cooled, long-life, one meter class space telescope which will be operated by NASA as a free-flying observatory for infrared astronomy, in the mid-1990's. To achieve its 5-year lifetime requirement (10 year goal), SIRTF must be replenished periodically with cryogenic helium and have its life-limited modular subsystems replaced; capability for contingency repair of warm components will also be provided in the Observatory design. A general description of the SIRTF Observatory is given, including options for the support systems (spacecraft). The overall servicing philosophy and plans are addressed with scheduling and needed support elements described. A proposed Space Station-based servicing scenario is described, including orbital transfer, servicing and checkout operations. A detailed description and timeline for liquid helium replenishment operations is provided, including a conceptual design and technology development program for the cryogenic helium transfer dewar (tanker). Finally, a preliminary SIRTF spares/logistics philosophy is outlined, including tradeoffs to be considered. Author

**A87-25449**
**A LONGBOAT FOR SPACE: THE EVOLUTION OF THE SATELLITE TRANSFER VEHICLE**
DAVID R. SCOTT (Scott Science and Technology, Inc., Lancaster, CA) International Space Business Review, vol. 1, July-Aug. 1986, p. 70-75.

The Satellite Transfer Vehicle (STV), which provides an economical and adaptable longboat for space satellites, is discussed. Market factors affecting satellite delivery and Space Shuttle upper-stage design are discussed, taking into account how the STV may fit into the Shuttle or the Ariane upper stage. The development and technical configuration, and commercial potential of the STV are examined. For the Space Station, the STV can satisfy early missions requirements defined for the NASA Orbital Transfer Vehicle. C.D.

**A87-26655*** Ball Aerospace Systems Div., Boulder, Colo.
**CONCEPTS FOR ON-ORBIT SERVICING OF SIRTF**
A. J. MORD, A. R. URBACH, M. E. POYER, L. C. ANDREOZZI, H. A. SNYDER (Ball Corp., Ball Aerospace Systems Div., Boulder, CO) et al. IN: Cryogenic optical systems and instruments II; Proceedings of the Meeting, Los Angeles, CA, Jan. 23, 24, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 13-20. refs
(Contract NAS2-11979)

The usable lifetime of the Space Infrared Telescope Facility (SIRTF) has been assumed to be limited to about two years by the lifetime of the superfluid helium carried in the telescope dewar. Concepts are presented for extending the system life by replenishing the cryogen on orbit, and for replacing the focal plane instruments. The operational aspects and the modifications to the baseline SIRTF are examined. It appears to be feasible to perform these servicing operations based on either the Space Shuttle or on the Space Station. Author

**A87-26656*** Lockheed Missiles and Space Co., Palo Alto, Calif.
**CRYOGENIC FLUID MANAGEMENT FOR LOW-G TRANSFER**
D. J. FRANK and D. E. JAEKLE, JR. (Lockheed Missiles and Space Co., Inc., Research and Development Div., Palo Alto, CA) IN: Cryogenic optical systems and instruments II; Proceedings of the Meeting, Los Angeles, CA, Jan. 23, 24, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 21-28.
(Contract NAS2-12051)

An account is given of design and operations criteria pertaining to low-g environment systems for the collection and delivery of liquid cryogens to a supply tank drain inlet in orbit. Analyses must assess the draining efficiencies of such devices, because the minimization of supply tank residual contents is of the essence. Settling accelerations, passive expulsion, and positive expulsion methods of fluid control have all been successfully demonstrated in orbit. Attention is given to the unique advantages and disadvantages of each method in view of different sets of requirements. O.C.

**A87-27603**
**SPACE LOGISTICS SYMPOSIUM, 1ST, HUNTSVILLE, AL, MAR. 24-26, 1987, TECHNICAL PAPERS**
Symposium sponsored by AIAA and Society of Logistics Engineers. New York, American Institute of Aeronautics and Astronautics, 1987, 167 p. For individual items see A87-27604 to A87-27624.

Logistics problems and possible solutions are identified for planned and proposed space, launch vehicle and ground support systems, services and capabilities. Systems engineering and logistics planning techniques are identified for launching, retrieving and repairing satellites and various free-flying platforms from the Orbiter and/or the Space Station. Alternative design approaches are explored for the construction, growth, maintenance and operation of the Space Station and SDI battle stations and ground support systems. Integrated ground support services are described as a necessary component that must be considered in the systems engineering of affordable, third generation of more-nearly fully reusable manned and unmanned launch systems. Finally, several

logistics analysis approaches, which must be applied at the inception of design studies, are delineated for inventory control, launch and maintenance, and repair and refurbishment of future space systems such as the Hubble Space Telescope. M.S.K.

**A87-27605#**

**FRONT END LOGISTICS INFLUENCE ON SPACE SYSTEM HARDWARE DESIGN**

CHARLES O. COOGAN (Acquisition Logistics Engineering, Worthington, OH) IN: Space Logistics Symposium, 1st, Huntsville, AL, Mar. 24-26, 1987, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1987, p. 5-11.
(AIAA PAPER 87-0658)

The application of logistics analysis in systems engineering of designs for future space systems are described. The next phase of space operations, i.e., long-duration large-scale missions, requires operational efficiency and reduced support burdens. Logistics analysis can be applied during the R&D phase of training activities and the definition of space systems maintenance requirements, for projecting the support requirements of production-line space components, for planning launch preparation activities, and for planning space servicing procedures, supplies and support requirements. Components and their lifetimes are considered; the combined subcomponent costs are a major determinant of systems costs, a view complementary to a systems engineering approach. Logistics analysis is useful in the formation of design concepts, and is relatively ineffective if applied during operational phases. M.S.K.

**A87-27609#**

**THE ROLE OF INVENTORY MANAGEMENT IN SATELLITE SERVICING**

KENNETH E. SHEPARD (Lockheed Missiles and Space Co., Inc., Huntsville, AL) IN: Space Logistics Symposium, 1st, Huntsville, AL, Mar. 24-26, 1987, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1987, p. 33-35.
(AIAA PAPER 87-0667)

The Inventory Management System (IMS) developed for aiding the program manager in planning and decision-making for on-orbit maintenance of the Hubble Space Telescope (HST) is described. The HST will have many custom components, a factor not encountered in logistics analysis of the support requirements of mass-production items on earth. The IMS, when fully configured, will have a database on the status and location of all spare equipment for the HST, will consider the changeout intervals, the costs of each item, and refurshment lead times, and will retain a history of repair, refurbishment and storage facilities for predictive purposes. The components list will cover 51,000 items from over 100 contractors. Definition of the database during development of the HST permitted parts tracking and establishment of the projected maintenance schedules, lead/turnaround times, and identification of critical spares. M.S.K.

**A87-27613#**

**REFURBISHMENT ISSUES FOR MODULAR SPACECRAFT**

MICHAEL J. MACKOWSKI (McDonnell Douglas Astronautics Co., Saint Louis, MO) IN: Space Logistics Symposium, 1st, Huntsville, AL, Mar. 24-26, 1987, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1987, p. 60-64.
(AIAA PAPER 87-0679)

The requirements for replacement of subsystems of the Modular Power Subsystem (MPS) for the NASA Multimission Modular Spacecraft (MMS) are discussed. The MPS is intended to be replaceable on-orbit for return to earth, refurbishment, and use on another spacecraft. It will first be necessary to establish a changeout schedule based on the failure rates of the subsystems and identify tests that show which parts are reusable. The factors of importance for a decision on whether or not to replace the MPS on the Solar Maximum Mission (SSM) are discussed. SMM, like Landsats 4 and 5, employ a MMS base configuration. Consideration of the lifetimes of the SSM MPS subsystems leads to recommendations of replacement and upgrading of the Ni-Cd batteries, the power regulatory system, the power control unit, the signal conditioning assembly and the remote interface units. M.S.K.

**A87-27614*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.

**LOGISTICS AND OPERATIONS INTEGRATION REQUIREMENTS TO SUPPORT SPACE STATION SERVICING OF FREE FLYING SPACECRAFT - OMV FLIGHT OPERATION**

JEROME A. BELL (NASA, Johnson Space Center, Houston, TX) and RICHARD T. MCGEEHAN (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Space Logistics Symposium, 1st, Huntsville, AL, Mar. 24-26, 1987, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1987, p. 65-77. refs
(AIAA PAPER 87-0686)

The logistics of OMV free-flyer servicing are examined, with emphasis on integrating the OMV operations into the overall STS-Space Station system. The depletion rate of consumables and lifetimes of free-flyer components are known quantities, which permits definition of a predictable maintenance schedule. Servicing with an OMV will depend on the position and capabilities of the OMV, Shuttle and Station when free-flyer maintenance is needed. Optimized orbital servicing of free-flyers will involve coordination of and resolution of schedule conflicts among STS, the OMV and the Station. The scheduled availability of any of the three components will be predicted in terms of probabilities that any one of the components will not be needed for another mission while performing the mission they are on. M.S.K.

**A87-27615#**

**REUSEABLE UNMANNED AUTOMATED RESUPPLY FREIGHTERS FOR SPACE STATION OPERATIONS**

GENNARO J. AVVENTO (USAF, Washington, DC) IN: Space Logistics Symposium, 1st, Huntsville, AL, Mar. 24-26, 1987, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1987, p. 78-81.
(AIAA PAPER 87-0687)

The key to the development of the Space Station is the manner in which logistical issues are handled. The current resupply strategy of the U.S. is completely dependent on the Space Shuttle. The weaknesses of this approach are in the limited availability and reduced payload capacity of the Shuttle. A fleet of reuseable unmanned automated supply freighters will supplement the role of the Shuttle and redress these weaknesses. These freighters will be launched by expendable launch vehicles (ELV) and be designed for eventual return to earth by the Shuttle for refurbishment and reuse. There are basic design requirements for such a space freighter and the system composition is highly dependent on the rendezvous approach taken and 'friendliness' of the Space Station. A typical mission profile to the station consists of four phases, each one critical to mission success. Author

**A87-27616#**

**A PRELIMINARY LOGISTICS SUPPORT CONCEPT FOR SPACE-BASED SDI ASSETS**

FRANK W. MOSS, PAT R. ODOM, CLANCY J. HATLEBERG, THOMAS P. OBRIEN, BOBBIE L. JONES (Advanced Technology, Inc., Hutsville, AL) et al. IN: Space Logistics Symposium, 1st, Huntsville, AL, Mar. 24-26, 1987, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1987, p. 94-102.
(AIAA PAPER 87-0689)

Preliminary results are presented of studies being performed to define a logistics-support design for space-based SDI assets and the associated ground-based equipment. The studies are considering the SDI systems architecture, the transportation architecture and the requirements for space assembly, maintenance and servicing. Several assumptions being made regarding the available launch systems, telerobotic systems, and the achievability of standardized parts are outlined, as are on-orbit hazards to repair crew and equipment. Optimized orbital positions for the weapons and surveillance systems being investigated are summarized, along with the types of on-orbit support missions that would be flown.

The hardware requirements for the ground- and space-based SDI components are discussed. M.S.K.

**A87-27617#**

**USE OF SUPPORT SIMULATION MODELING TECHNIQUES IN THE DEVELOPMENT OF LOGISTICS SUPPORT CONCEPTS FOR SDI ORBITAL PLATFORMS AND CONSTELLATIONS**

RICHARD FLOWERREE, SCOTT BENSON, and MARK MCCRAY (General Dynamics Corp., Space Systems Div., San Diego, CA) IN: Space Logistics Symposium, 1st, Huntsville, AL, Mar. 24-26, 1987, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1987, p. 103-115.
(AIAA PAPER 87-0690)

Simulation modeling techniques being applied to explore logistics support systems for SDI orbital platforms are described. The studies are targeted at optimizing the systems/subsystems redundancy levels, defining constellation servicing schedules, identifying appropriate man-tended servicing missions, and quantifying the reusable and consumable components necessary for ensuring a given level of system availability. Consideration is also being given to robotics in on-orbit maintenance, constellation regrouping/reconfiguration after engagement, and the ground-based support services necessary for given levels of space systems deployment and availability. War-game, design synthesis and space transportation models being used in the studies are summarized. Sample results are provided from the SAGITTAR experiment, a simulation of the fuel, orbital replacement units, and other consumables needed for a platform. M.S.K.

**A87-27621#**

**SPACE LOGISTICS SUPPORT TO MILITARY SPACE SYSTEMS**

JOHN C. BAKER (bd Systems, Inc., Torrance, CA) and WILLIAM MOROSOFF IN: Space Logistics Symposium, 1st, Huntsville, AL, Mar. 24-26, 1987, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1987, p. 138-144.
(AIAA PAPER 87-0694)

Deficiencies in current space support capabilities have been examined and compared to evolving infrastructure requirements, both with and without SDI. The resulting needs are documented in the launch, on-orbit and C3 areas. Technology advances and methods of operation that will be required to bring space logistics to an appropriate level so that military activity can become effective in space are identified and documented, and a 10 yr is presented. Supportability is shown to be an important force multiplier for military space systems. Author

**A87-27959#**

**ELECTRON AND VIBRATIONAL ENERGY CONSERVATION EQUATIONS FOR AEROASSISTED ORBITAL TRANSFER VEHICLES**

KATSUHISA KOURA (National Aerospace Laboratory, Tokyo, Japan) AIAA Journal (ISSN 0001-1452), vol. 25, Jan. 1987, p. 178, 179. refs

An account is given of the thermal and chemical nonequilibrium flows that will be encountered by aeroassisted orbital transfer vehicles. The expressions for the rate of electron energy loss due to rotational excitations of molecular species and the rate of electron energy loss due to vibrational excitations of molecular species are derived. O.C.

**A87-29441**

**AEROSPACE TESTING SEMINAR, 9TH, LOS ANGELES, CA, OCT. 15-17, 1985, PROCEEDINGS**

Seminar sponsored by the Institute of Environmental Sciences and Aerospace Corp. Mount Prospect, IL, Institute of Environmental Sciences, 1986, 268 p. For individual items see A87-29442 to A87-29471.

Papers are presented on the qualification/acceptance program for the Hubble Space Telescope, launch vehicle platform and high-energy upper stage acceptance testing, the integrated spacecraft automated test system, characteristics of electromagnetic interference generated by arc discharging, and strain gage selection and bonding techniques for application in a cryogenic-pyrotechnic environment. Topics discussed include a design verification system for advanced aerospace engines, a Space Station propulsion system test bed, test and verification impact on commercial Space Station operations, cost effective management of space venture risks, and automated microwave testing of spacecraft. Consideration is given to vibration testing of large spacecraft; transfer-orbit-stage off-line processing; utilization, testing, and maintenance of multimission hardware; payload vibroacoustics for Shuttle peculiar environments; and automatic, integrated facility record systems for Shuttle processing at Vandenberg AFB. I.F.

**A87-29456#**

**TEST AND VERIFICATION IMPACT ON COMMERCIAL SPACE STATION OPERATIONS**

WILLIAM A. GOOD and LEWIS O. SHROYER (Rockwell International Corp., Pittsburgh, PA) IN: Aerospace Testing Seminar, 9th, Los Angeles, CA, Oct. 15-17, 1985, Proceedings . Mount Prospect, IL, Institute of Environmental Sciences, 1986, p. 125-130.

Test and verification procedures for the Space Station operations are discussed. The relation between the design, operations, and software for the Space Station is examined. The roles of design, operations, and software engineers in creating successful commercial Space Station operations are described. I.F.

**A87-31133*#** General Dynamics Corp., San Diego, Calif.

**EVALUATION OF ON-ORBIT CRYOGENIC PROPELLANT DEPOT OPTIONS FOR THE ORBITAL TRANSFER VEHICLE**

J. R. SCHUSTER, F. O. BENNETT, M. W. LIGGETT, C. N. TORRE (General Dynamics Corp., Space Systems Div., San Diego, CA), and N. BROWN (NASA, Marshall Space Flight Center, Huntsville, AL) ASME, Intersociety Cryogenics Symposium, 6th, New Orleans, LA, Nov. 16-21, 1986, Paper. 43 p. refs
(Contract NAS8-36612)

An orbital cryogenic propellant storage facility will be required for a space-based Orbital Transfer Vehicle. The facility tanks will have features to permit fluid acquisition and transfer in low gravity and to limit cryogen boiloff caused by environmental heating. Boiloff management features will include thick multilayer insulation, vapor-cooled shields, low conductance structural supports and penetrations, and possibly refrigeration systems. Author

**N87-10110*#** Boeing Aerospace Co., Kennedy Space Center, Fla.

**ORBITAL TRANSFER VEHICLE LAUNCH OPERATIONS STUDY. VOLUME 1: EXECUTIVE SUMMARY Final Report**

7 Mar. 1986 12 p
(Contract NAS10-11165)
(NASA-CR-179701; NAS 1.26:179701) Avail: NTIS HC A02/MF A01 CSCL 22D

The purpose was to use the operational experience at the launch site to identify, describe and quantify the operational impacts of the various configurations on the Kennedy Space Center (KSC) and/or space station launch sites. Orbital Transfer Vehicle (OTV) configurations are being developed/defined by contractor teams. Lacking an approved configuration, the KSC Study Team defined a Reference Configuration to be used for this study. This configuration then become the baseline for the identification of the facilities, personnel and crew skills required for processing the OTV in a realistic manner that would help NASA achieve the lowest possible OTV life cycle costs. As the study progressed, researchers' initial apraisal that the vehicle, when delivered, would be a sophisticated, state-of-the-art vehicle was reinforced. It would be recovered and reused many times so the primary savings to be gained would be in the recurring-cycle of the vehicle operations--even to the point where it would be beneficial to break from tradition and make a significant expenditure in the development of processing facilities at the beginning of the program.

**N87-10111*#** Boeing Aerospace Co., Kennedy Space Center, Fla.
**ORBITAL TRANSFER VEHICLE LAUNCH OPERATIONS STUDY. VOLUME 2: DETAILED SUMMARY**
7 Mar. 1986 181 p
(Contract NAS10-11165)
(NASA-CR-179791; NAS 1.26:179791) Avail: NTIS HC A09/MF A01 CSCL 22D

A series of Operational Design Drivers were identified. Several of these could have significant impact(s) on program costs. These recommendations, for example, include such items as: complete factory assembly and checkout prior to shipment to the ground launch site to make significant reductions in time required at the launch site as well as overall manpower required to do this work; minimize use of nonstandard equipment when orbiter provided equipment is available; and require commonality (or interchangeability) of subsystem equipment elements that are common to the space station, Orbit Maneuvering Vehicles, and/or Orbit Transfer Vehicles. Several additional items were identified that will require a significant amount of management attention (and direction) to resolve. Key elements of the space based processing plans are discussed. B.G.

**N87-10883*#** Boeing Aerospace Co., Kennedy Space Center, Fla.
**ORBITAL TRANSFER VEHICLE LAUNCH OPERATIONS STUDY: AUTOMATED TECHNOLOGY KNOWLEDGE BASE, VOLUME 4 Final Report**
7 Mar. 1986 124 p
(Contract NAS10-11165)
(NASA-CR-179706; NAS 1.26:179706) Avail: NTIS HC A06/MF A01 CSCL 22D

A simplified retrieval strategy for compiling automation-related bibliographies from NASA/RECON is presented. Two subsets of NASA Thesaurus subject terms were extracted: a primary list, which is used to obtain an initial set of citations; and a secondary list, which is used to limit or further specify a large initial set of citations. These subject term lists are presented in Appendix A as the Automated Technology Knowledge Base (ATKB) Thesaurus. M.G.

**N87-10959*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**STATUS OF ADVANCED PROPULSION FOR SPACE BASED ORBITAL TRANSFER VEHICLE**
L. P. COOPER and D. D. SCHEER 1986 32 p Presented at the 37th Congress of the International Astronautical Federation, Innsbruck, Austria, 4-11 Oct. 1986
(NASA-TM-88848; E-3238; NAS 1.15:88848; IAF-86-183) Avail: NTIS HC A03/MF A01 CSCL 21H

A new Orbital Transfer Vehicle (OTV) propulsion system will be required to meet the needs of space missions beyond the mid-1990's. As envisioned, the advanced OTV will be used in conjunction with Earth-to-orbit vehicles, Space Station, and Orbit Maneuvering Vehicle. The OTV will transfer men, large space structures, and conventional payloads between low Earth and higher energy orbits. Space probes carried by the OTV will continue the exploration of the solar system. When lunar bases are established, the OTV will be their transportation link to Earth. NASA is currently funding the development of technology for advanced propulsion concepts for future Orbital Transfer Vehicles. Progress in key areas during 1986 is presented. Author

**N87-12580*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**LUNAR LABORATORY**
P. W. KEATON (Los Alamos National Lab., N. Mex.) and M. B. DUKE 1986 11 p Presented at the Committee on Space Research (COSPAR), Toulouse, France, 30 Jun. 1986 Sponsored in part by NASA
(Contract W-7405-ENG-36)
(NASA-TM-89209; NAS 1.15:89209; DE86-0123433; LA-UR-86-2213; CONF-8606145-1) Avail: NTIS HC A02/MF A01

An international research laboratory can be established on the Moon in the early years of the 21st Century. It can be built using the transportation system now envisioned by NASA, which includes a space station for Earth orbital logistics and orbital transfer vehicles for Earth-Moon transportation. A scientific laboratory on the Moon would permit extended surface and subsurface geological exploration; long-duration experiments defining the lunar environment and its modification by surface activity; new classes of observations in astronomy; space plasma and fundamental physics experiments; and lunar resource development. The discovery of a lunar source for propellants may reduce the cost of constructing large permanent facilities in space and enhance other space programs such as Mars exploration. DOE

**N87-13167*#** McDonnell-Douglas Astronautics Co., Houston, Tex.
**ADVANCED EVA SYSTEM DESIGN REQUIREMENTS STUDY Final Technical Report**
Jan. 1986 248 p
(Contract NAS9-17299)
(NASA-CR-171942; NAS 1.26:171942; MDC-W0072) Avail: NTIS HC A11/MF A01 CSCL 05H

Design requirements and criteria for the Space Station Advanced Extravehicular Activity System (EVAS) including crew enclosures, portable life support systems, maneuvering propulsion systems, and related extravehicular activity (EVA) support equipment were defined and established. The EVA mission requirements, environments, and medical and physiological requirements, as well as opertional, procedures, and training issues were considered. B.G.

**N87-13459#** MATRA Espace, Paris-Velizy (France).
**RENDEZVOUS AND DOCKING (RVD) SIMULATION PROGRAM Final Report**
B. CLAUDINON, R. WORSWICK, and C. PAUVERT Paris, France ESA Mar. 1985 78 p Prepared in cooperation with Locica Ltd, London, England
(Contract ESA-5347/83-NL-BI(SC))
(MATRA-EPT/DT/VTO68/062; ESA-CR(P)-2251; ETN-86-98128) Avail: NTIS HC A05/MF A01

A computer program to simulate spacecraft docking homing and final approach phases which include many subphases or modes interconnected through mode change criteria was developed. The program can simulate each mode and chain them according to user defined switching criteria. Modes proposed are: coast; homing (multiple arc simplified approach); stand-by point acquisition; stationkeeping on target orbit; flyaround (or docking axis acquisition); stationkeeping in docking corridor using the radar sensor; camera sensor acquisition (pointing); radar sensor acquisition (pointing); stationkeeping on the docking axis using the camera sensor; translation according to a parabolic profile; and translation at constant velocity and all back-up phases for retreat. Spacecraft equipment, dynamics, and kinematics (including orbital motion) are also simulated. ESA

**N87-14359#** MATRA Espace, Paris-Velizy (France).
**RENDEZVOUS AND DOCKING (RVD) GUIDANCE SIMULATION PROGRAM, RIDER 2 Final Report**
C. PAUVERT and R. WORSWICK Paris, France ESA Jan. 1986 212 p Prepared in cooperation with Logica Ltd., London, England
(Contract ESA-5347/83-NL-BI(SC))
(MATRA-EPT/DT/VT068/012; ESA-CR(P)-2238; ETN-86-98116)
Avail: NTIS HC A10/MF A01

Propellant sloshing and structural flexibility were added to the RVD Simulation Program (now called RVD Guidance Simulator). The performance of the modified program for realistic mission configurations and docking conditions was evaluated. The basic structure of the RVD Guidance Simulator (RVD GS) is kept, but to save computing time, a basic two body (chaser+target) version of the program was developed, rather than a three body version including a dummy Earth, previously used to overcome numerical problems. Simulations provide sets of typical docking conditions in terms of spacecraft relative position, velocity, attitude, and attitude rate for various geometric, dynamic, and control configurations. Worst case parameters are derived from the simulations as typical initial conditions to the Docking Simulation Program. ESA

**N87-15259*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**SPACE SPIDER CRANE Patent Application**
IAN O. MACCONOCHIE, inventor (to NASA), JACK E. PENNINGTON, inventor (to NASA), CHARLES F. BRYAN, JR., inventor (to NASA), MARTIN M. MIKULAS, JR., inventor (to NASA), and REBECCA L. KINKEAD, inventor (to NASA) 30 Sep. 1986 18 p
(NASA-CASE-LAR-13411-1SB; NAS 1.71:LAR-13411-1; US-PATENT-APPL-SN-913432) Avail: NTIS HC A02/MF A01 CSCL 84G

A space spider crane for the movement, placement, and/or assembly of various components on or in the vicinity of a space structure is described. As permanent space structures are utilized by the space program, a means will be required to transport cargo and perform various repair tasks. A space spider crane comprising a small central body with attached manipulators and legs fulfills this requirement. The manipulators may be equipped with constant pressure gripping end effectors or tools to accomplish various repair tasks. The legs are also equipped with constant pressure gripping end effectors to grip the space structure. Control of the space spider crane may be achieved either by computer software or a remotely situated human operator, who maintains visual contact via television cameras mounted on the space spider crane. One possible walking program consists of a parallel motion walking program whereby the small central body alternatively leans forward and backward relative to end effectors. NASA

**N87-16772*#** Berry Coll., Mount Berry, Ga. Dept. of Physics.
**A STUDY OF RADAR CROSS SECTION MEASUREMENT TECHNIQUES**
MALCOLM W. MCDONALD *In* NASA. Marshall Space Flight Center Research Reports: 1986 NASA/ASEE Summer Faculty Fellowship Program 22 p Nov. 1986
Avail: NTIS HC A99/MF E04 CSCL 17I

Past, present, and proposed future technologies for the measurement of radar cross section were studied. The purpose was to determine which method(s) could most advantageously be implemented in the large microwave anechoic chamber facility which is operated at the antenna test range site. The progression toward performing radar cross section measurements of space vehicles with which the Orbital Maneuvering Vehicle will be called upon to rendezvous and dock is a natural outgrowth of previous work conducted in recent years of developing a high accuracy range and velocity sensing radar system. The radar system was designed to support the rendezvous and docking of the Orbital Maneuvering Vehicle with various other space vehicles. The measurement of radar cross sections of space vehicles will be necessary in order to plan properly for Orbital Maneuvering Vehicle rendezvous and docking assignments. The methods which were studied include: standard far-field measurements; reflector-type compact range measurements; lens-type compact range measurement; near field/far field transformations; and computer predictive modeling. The feasibility of each approach is examined. Author

**N87-17472*#** Ford Aerospace and Communications Corp., Palo Alto, Calif.
**COMMUNICATIONS SATELLITE SYSTEMS OPERATIONS WITH THE SPACE STATION. VOLUME 1: EXECUTIVE SUMMARY Final Report, Jul. 1985 - Sep. 1986**
K. PRICE, J. DIXON, and C. WEYANDT Feb. 1987 17 p
(Contract NAS3-24253)
(NASA-CR-179526; NAS 1.26:179526) Avail: NTIS HC A02/MF A01 CSCL 12B

The benefits of new space-based activities are quantified and the impacts on the satellite design and the space station are assessed. B.G.

**N87-17473*#** Ford Aerospace and Communications Corp., Palo Alto, Calif.
**COMMUNICATIONS SATELLITE SYSTEMS OPERATIONS WITH THE SPACE STATION, VOLUME 2 Final Report, Jul. 1985 - Sep. 1986**
K. PRICE, J. DIXON, and C. WEYANDT Feb. 1987 190 p
(Contract NAS3-24253)
(NASA-CR-179527; NAS 1.26:179527) Avail: NTIS HC A09/MF A01 CSCL 12B

A financial model was developed which described quantitatively the economics of the space segment of communication satellite systems. The model describes the economics of the space system throughout the lifetime of the satellite. The expected state-of-the-art status of communications satellite systems and operations beginning service in 1995 were assessed and described. New or enhanced space-based activities and associated satellite system designs that have the potential to achieve future communications satellite operations in geostationary orbit with improved economic performance were postulated and defined. Three scenarios using combinations of space-based activities were analyzed: a spin stabilized satellite, a three axis satellite, and assembly at the Space Station and GEO servicing. Functional and technical requirements placed on the Space Station by the scenarios were detailed. Requirements on the satellite were also listed. B.G.

**N87-17726*#** Eagle Engineering, Inc., Houston, Tex.
**EARTH VICINITY TRADES AND OPTIONS**
WILLIAM R. STUMP, GUS R. BABB, and HUBERT P. DAVIS *In* NASA. Marshall Space Flight Center Manned Mars Missions. Working Group Papers, Volume 1, Section 1-4 p 53-65 May 1986
Avail: NTIS HC A22/MF A01 CSCL 22A

The options for recovering a returned manned Mars spacecraft are surveyed. Earth parking orbits from libration point to low circular are discussed, with a 500 km perigee, 24 hour period elliptical orbit chosen as a baseline for further calculation. Several techniques for recovering up to 100 metric tons of returned spacecraft are investigated, including recovery by a low Earth orbit (LEO) based orbit transfer vehicle (OTV) pushing the spacecraft to LEO, and OTV transporting and aerobrake to the spacecraft, and an OTV delivering propellant to the spacecraft. Methods utilizing OTVs results in less total mass in LEO, but may not be the minimum cost solutions if significant development and testing are required. Author

**N87-17738*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**CONCEPT FOR A MANNED MARS FLYBY**
BARNEY B. ROBERTS *In* NASA. Marshall Space Flight Center Manned Mars Missions. Working Group Papers, Volume 1, Section 1-4 p 203-218 May 1986
Avail: NTIS HC A22/MF A01 CSCL 22A

A concept is presented for a three man crew to fly by the planet Mars. The ground rule for the study is to execute the mission as quickly as possible which dictates using late 1990's technologies and space infrastructure. The proposed mission described herein uses a preliminary concept for the agency's Manned Orbit Transfer Vehicle (MOTV) and proposed space station elements. The space vehicle will depart from the LEO space station and is delivered to Low Earth Orbit (LEO) by a future launch vehicle of a Shuttle Derived Launch Vehicle (SDV) class. The trajectory parameters are chosen such that the mission duration is on the order of one year, with a two and one-half hour period within ten planetary radii of Mars. If the issues of acceptable crew g loads and entry vehicle heat load can be resolved, then the returning vehicle can aerobrake at Earth into a space station compatible orbit. Otherwise, a propulsive maneuver will be required to reduce vehicle velocity prior to Earth entry interface. It is possible to execute a mission of reasonable capability at an initial LEO departure weight of 716,208 pounds for the aerobraked case of 1,350,000 pounds for the propulsive case. Author

**N87-17742*#** Los Alamos National Lab., N. Mex. Geophysics Group.
**MARS BASE BUILDUP SCENARIOS**
J. D. BLACIC *In* NASA. Marshall Space Flight Center Manned Mars Missions. Working Group papers, Volume 1, Section 1-4 p 252-262 May 1986
Avail: NTIS HC A22/MF A01 CSCL 22A

Two Mars surface based build-up scenarios are presented in order to help visualize the mission and to serve as a basis for trade studies. In the first scenario, direct manned landings on the Martian surface occur early in the missions and scientific investigation is the main driver and rationale. In the second senario, Earth development of an infrastructure to exploit the volatile resources of the Martian moons for economic purposes is emphasized. Scientific exploration of the surface is delayed at first in this scenario relative to the first, but once begun develops rapidly, aided by the presence of a permanently manned orbital station. Author

**N87-17746*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**MANNED MARS MISSION EARTH-TO-ORBIT (ETO) DELIVERY AND ORBIT ASSEMBLY OF THE MANNED MARS VEHICLE**
B. BARISA and G. SOLMON *In its* Manned Mars Missions. Working Group Papers, Volume 1, Section 1-4 p 306-315 May 1986
Avail: NTIS HC A22/MF A01 CSCL 22A

The initial concepts developed for the in-orbit assembly of a Manned Mars Vehicle and for the Earth-to-Orbit (ETO) delivery of the required hardware and propellant are presented. Two (2) Mars vehicle concepts (all-propulsive and all-aerobrake) and two (2) ETO Vehicle concepts were investigated. Both Mars Vehicle concepts are described in Reference 1, and both ETO Vehicle concepts are described in Reference 2. The all-aerobrake configuration reduces the number of launches and time required to deliver the necessary hardware/propellent to orbit. Use of the larger of the 2 ETO Vehicles (HLLV) further reduces the number of launches and delivery time; however, this option requires a completely new vehicle and supporting facilities. Author

**N87-17747*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**SPACE VEHICLE CONCEPTS**
MICHAEL TUCKER, OLIVER MEREDITH, and BOBBY BROTHERS *In its* Manned Mars Missions. Working Group Papers, Volume 1, Section 1-4 p 316-341 May 1986
Avail: NTIS HC A22/MF A01 CSCL 22B

Several concepts of chemical-propulsion Space Vehicles (SVs) for manned Mars landing missions are presented. For vehicle sizing purposes, several specific missions were chosen from opportunities in the late 1990's and early 2000's, and a vehicle system concept is then described which is applicable to the full range of missions and opportunities available. In general, missions utilizing planetary opposition alignments can be done with smaller vehicles than those utilizing planetary opposition alignments. The conjunction missions have a total mission time of about 3 years, including a required stay-time of about 60 days. Both types of missions might be desirable during a Mars program, the opposition type for early low-risk missions and/or for later unmanned cargo missions, and the conjunction type for more extensive science/exploration missions and/or for Mars base activities. Since the opposition missions appeared to drive the SV size more severely, there were probably more cases examined for them. Some of the concepts presented utilize all-propulsive braking, some utilize and all aerobraking approach, and some are hybrids. Weight statements are provided for various cases. Most of the work was done on 0-g vehicle concepts, but partial-g and 1-g concepts are also provided and discussed. Several options for habitable elements are shown, such as large-diameter modules and space station (SS) types of modules. Author

**N87-17760*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**MANNED MARS MISSION. WORKING GROUP PAPERS, VOLUME 2, SECTION 5 - APPENDIX**
MICHAEL B. DUKE, ed. and PAUL W. KEATON, ed. May 1986 559 p Workshop held in Huntsville, Ala., 10-14 Jun. 1985
(NASA-TM-89321-VOL-2; NASA-M002-VOL-2; NAS 1.15:89321-VOL-2) Avail: NTIS HC A24/MF A01 CSCL 22A

Topics discussed include: science investigations and issues; life science/medical issues; subsystems and technology development requirements; political issues; and impacts on other programs.

**N87-17805*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**OTV IMPACTS AND INTERACTIONS**
BARNEY B. ROBERTS *In* NASA. Marshall Space Flight Center Manned Mars Mission. Working Group Papers, V. 2, Sect. 5, App. p 1011-1017 May 1986
Avail: NTIS HC A24/MF A01 CSCL 22A

The possible impacts and interactions of the agency's planning activities for the Orbit Transfer Vehicle (OTV) that is tentatively scheduled for initial operational capability in the late 1990's are identified. In general, the various Mars missions require vehicles of significant size and performance far greater than that provided by any OTV configuration currently being seriously considered. Therefore, interactions and impacts on these current concepts are minimal. These impacts and interactions fall into categories of technologies, systems, and operations. Each category is addressed. Author

**N87-17806*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**SPACE STATION UTILIZATION AND COMMONALITY**
JOHN BUTLER *In* NASA. Marshall Space Flight Center Manned Mars Mission. Working Group Papers, V. 2, Sect. 5, App. p 1018-1034 May 1986
Avail: NTIS HC A24/MF A01 CSCL 22A

Several potential ways of utilizing the space station, including utilization of learning experiences (such as operations), utilization of specific elements of hardware which can be largely common between the SS and Mars programs, and utilization of the on-orbit

SS for transportation node functions were identified and discussed. The probability of using the SS in all of these areas seems very good. Three different ways are discussed of utilizing the then existing Low Earth Orbit (LEO) SS for operational support during assembly and checkout of the Mars Space Vehicle (SV): attaching the SV to the SS; allowing the SV to co-orbit near the SS; and a hybrid of the first 2 ways. Discussion of each of these approaches is provided, and the conclusion is reached that either the co-orbiting or hybrid approach might be preferable. Artists' conception of the modes are provided, and sketches of an assembly system concept (truss structure and subsystems derivable from the SS) which could be used for co-orbiting on-orbit assembly support are provided.
Author

**N87-17807*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**SPACE STATION SUPPORT OF MANNED MARS MISSIONS**
ALAN C. HOLT *In* NASA. Marshall Space Flight Center Manned Mars Mission. Working Group Papers, V. 2, Sect. 5, App. p 1035-1044 May 1986
Avail: NTIS HC A24/MF A01 CSCL 22A

The assembly of a manned Mars interplanetary spacecraft in low Earth orbit can be best accomplished with the support of the space station. Station payload requirements for microgravity environments of .001 g and pointing stability requirements of less than 1 arc second could mean that the spacecraft may have to be assembled at a station-keeping position about 100 meters or more away from the station. In addition to the assembly of large modules and connective structures, the manned Mars mission assembly tasks may include the connection of power, fluid, and data lines and the handling and activation of components for chemical or nuclear power and propulsion systems. These assembly tasks will require the use of advanced automation and robotics in addition to Orbital Maneuvering Vehicle and Extravehicular Activity (EVA) crew support. Advanced development programs for the space station, including on-orbit demonstrations, could also be used to support manned Mars mission technology objectives. Follow-on studies should be conducted to identify space station activities which could be enhanced or expanded in scope (without significant cost and schedule impact) to help resolve key technical and scientific questions relating to manned Mars missions.
Author

**N87-17838*#** McDonnell-Douglas Astronautics Co., Houston, Tex.
**ADVANCED EVA SYSTEM DESIGN REQUIREMENTS STUDY, EXECUTIVE SUMMARY Final Technical Report**
Jan. 1986 45 p
(Contract NAS9-17299)
(NASA-CR-171960; NAS 1.26:171960; MDC-W0072) Avail: NTIS HC A03/MF A01 CSCL 22B

Design requirements and criteria for the space station advanced Extravehicular Activity System (EVAS) including crew enclosures, portable life support systems, maneuvering propulsion systems, and related EVA support equipment were established. The EVA mission requirements, environments, and medical and physiological requirements, as well as operational, procedures and training issues were considered.
B.G.

**N87-18333*#** TRW Defense Systems Group, Houston, Tex. System Development Div.
**RELBET 4.0 USER'S GUIDE**
F. C. CERBINS, B. P. HUYSMAN, J. K. KNOEDLER, P. S. KWONG, L. A. PIENIAZEK, and S. W. STROM 23 Dec. 1986 286 p
(Contract NAS9-17554)
(NASA-CR-171973; NAS 1.26:171973; TRW-47467-H010-UX-00)
Avail: NTIS HC A13/MF A01 CSCL 09B

This manual describes the operation and use of RELBET 4.0 implemented on the Hewlett Packard model 9000. The RELBET System is an integrated collection of computer programs which support the analysis and post-flight reconstruction of vehicle to vehicle relative trajectories of two on-orbit free-flying vehicles: the Space Shuttle Orbiter and some other free-flyer. The manual serves both as a reference and as a training guide. Appendices provide experienced users with details and full explanations of program usage. The body of the manual introduces new users to the system by leading them through a step by step example of a typical production. This should equip the new user both to execute a typical production process and to understand the most significant variables in that process.
Author

**N87-18581*#** Science Applications International Corp., Schaumberg, Ill. Advanced Planning and Analysis Div.
**SATELLITE SERVICES SYSTEM PROGRAM PLAN**
STEPHEN J. HOFFMAN Jul. 1985 88 p
(Contract NAS9-17207)
(NASA-CR-171969; NAS 1.26:171969; SAIC-85/1762; SAIC-1-120-778-S19) Avail: NTIS HC A05/MF A01 CSCL 22A

The purpose is to determine the potential for servicing from the Space Shuttle Orbiter and to assess NASA's role as the catalyst in bringing about routine on-orbit servicing. Specifically this study seeks to determine what requirements, in terms of both funds and time, are needed to make the Shuttle Orbiter not only a transporter of spacecraft but a servicing vehicle for those spacecraft as well. The scope of this effort is to focus on the near term development of a generic servicing capability. To make this capability truly generic and attractive requires that the customer's point of veiw be taken and transformed into a widely usable set of hardware. And to maintain a near term advent of this capability requires that a minimal reliance be made on advanced technology. With this background and scope, this study will proceed through three general phases to arrive at the desired program costs and schedule. The first step will be to determine the servicing requirements of the user community. This will provide the basis for the second phase which is to develop hardware concepts to meet these needs. Finally, a cost estimate will be made for each of the new hardware concepts and a phased hardware development plan will be established for the acquisition of these items based on the inputs obtained from the user community.
Author

**N87-18582*#** Science Applications International Corp., Schaumberg, Ill. Advanced Planning and Analysis Div.
**AN INVESTIGATION OF SELECTED ON-ORBIT SATELLITE SERVICING ISSUES**
STEPHEN J. HOFFMAN Nov. 1986 157 p
(Contract NAS9-17207)
(NASA-CR-171968; NAS 1.26:171968; SAIC-86/1942; SAIC-1-120-778-S22) Avail: NTIS HC A08/MF A01 CSCL 22A

The results of three separate investigations performed by Science Applications International Corporation (SAIC) between August 1985 and October 1986 as the second phase of the two-phase Satellite Services System Program Plan contract for the Engineering Directorate of the Lyndon B. Johnson Space Center are discussed. The objectives of the first phase of this contract (reported in SAIC-85/1762) were to determine the potential for servicing a diverse range of spacecraft from the Space Shuttle Orbiter and to assess NASA's role as the catalyst in enabling routine on-orbit servicing. The second area of investigation was prompted by the need to understand satellite servicing requirements in the far term (1995 to 2010) and how results from the first phase of this contract could support these requirements. The mission model developed during the first phase was extended using new data and information from studies which address the later time period. The third area of investigation looked at a new servicing mode which had not been studied previously. This mode involves the on-orbit exchange of very large modules with masses greater than approximately 9,000 kilograms and/or lengths greater than approximately nine meters. The viewgraphs used for the final briefing for each of the three investigations, as presented to NASA are given.
Author

**N87-18584*#** Martin Marietta Aerospace, Denver, Colo. Fluid Systems Dept.
**ORBITAL FLUID SERVICING AND RESUPPLY OPERATIONS**
R. N. EBERHARDT and W. J. BAILEY 1987 65 p
(Contract NAS9-17585)
(NASA-CR-180238; NAS 1.26:180238) Avail: NTIS HC A04/MF A01 CSCL 22A

The capability to reservice spacecraft and satellites with expendable fluids will provide significant increases in the usability, operational efficiency and cost effectiveness of in-space systems. Initial resupply will be accomplished from the Orbiter cargo bay starting with monopropellant servicing which will eventually be extended to servicing of bipropellants and pressurants. Other fluids, such as freon, ammonia, methanol, superfluid helium, and liquid/gaseous nitrogen may also need to be resupplied once a space station becomes a reality. These fluids/gases are required for subsystem working fluid replacement and payload/experiment fluid replenishment. A logistics module operating on a 90 day schedule is planned for space station servicing. Resupplying hundreds of thousands of pounds of cryogenic propellants and reactants for users such as the Orbital Transfer Vehicle (OTV) also represents future logistics challenges. Implementation of on-orbit fluid transfer requires solving many problems including fluid management in the low-g environment, system docking and interface mating, configuration of user friendly avionics to monitor and control the entire servicing operation, and minimized maintenance and enhanced reliability. Candidate fluid transfer methods and possible gas transfer methods are discussed, and preliminary storable monopropellant and bipropellant tanker designs are summarized. Author

**N87-19539*#** Pratt and Whitney Aircraft, West Palm Beach, Fla. Government Products Div.
**CRYOGENIC GEAR TECHNOLOGY FOR AN ORBITAL TRANSFER VEHICLE ENGINE AND TESTER DESIGN Final Report, Apr. - Nov. 1985**
M. CALANDRA and G. DUNCAN Jun. 1986 116 p
(Contract NAS3-23858)
(NASA-CR-175102; NAS 1.26:175102; PW/GPD-FR-19177)
Avail: NTIS HC A06/MF A01 CSCL 22B

Technology available for gears used in advanced Orbital Transfer Vehicle rocket engines and the design of a cryogenic adapted tester used for evaluating advanced gears are presented. The only high-speed, unlubricated gears currently in cryogenic service are used in the RL10 rocket engine turbomachinery. Advanced rocket engine gear systems experience operational load conditions and rotational speed that are beyond current experience levels. The work under this task consisted of a technology assessment and requirements definition followed by design of a self-contained portable cryogenic adapted gear test rig system. Author

**N87-20351*#** McDonnell-Douglas Astronautics Co., St. Louis, Mo.
**ADVANCED EVA SYSTEM DESIGN REQUIREMENTS STUDY: EVAS/SPACE STATION SYSTEM INTERFACE REQUIREMENTS**
T. G. WOODS 15 Nov. 1985 122 p
(Contract NAS9-17299)
(NASA-CR-171981; NAS 1.26:171981; MDC-W0070) Avail: NTIS HC A06/MF A01 CSCL 22B

The definition of the Extravehicular Activity (EVA) systems interface requirements and accomodations for effective integration of a production EVA capability into the space station are contained. A description of the EVA systems for which the space station must provide the various interfaces and accomodations are provided. The discussion and analyses of the various space station areas in which the EVA interfaces are required and/or from which implications for EVA system design requirements are derived, are included. The rationale is provided for all EVAS mechanical, fluid, electrical, communications, and data system interfaces as well as exterior and interior requirements necessary to facilitate EVA operations. Results of the studies supporting these discussions are presented in the appendix. B.G.

**N87-21151*#** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
**SUPERFLUID HELIUM ON ORBIT TRANSFER (SHOOT)**
MICHAEL J. DIPIRRO *In* NASA. Lewis Research Center Microgravity Fluid Management Symposium p 125-136 Apr. 1987
Avail: NTIS HC A10/MF A01 CSCL 22A

A number of space flight experiments and entire facilities require superfluid helium as a coolant. Among these are the Space Infrared Telescope Facility (SIRTF), the Large Deployable Reflector (LDR), the Advanced X-ray Astrophysics Facility (AXAF), the Particle Astrophysics Magnet Facility (PAMF or Astromag), and perhaps even a future Hubble Space Telescope (HST) instrument. Because these systems are required to have long operational lifetimes, a means to replenish the liquid helium, which is exhausted in the cooling process, is required. The most efficient method of replenishment is to refill the helium dewars on orbit with superfluid helium (liquid helium below 2.17 Kelvin). To develop and prove the technology required for this liquid helium refill, a program of ground and flight testing was begun. The flight demonstration is baselined as a two flight program. The first, described in this paper, will prove the concepts involved at both the component and system level. The second flight will demonstrate active astronaut involvement and semi-automated operation. The current target date for the first launch is early 1991.

# 17

# SPACE ENVIRONMENT

Includes description of the space environment and effects on Space Station subsystems. Includes requirements for Space Station to accommodate this environment.

**A87-11355*#** National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
**AN ESTIMATE OF THE OUTGASSING OF SPACE PAYLOADS AND ITS GASEOUS INFLUENCE ON THE ENVIRONMENT**
J. J. SCIALDONE (NASA, Goddard Space Flight Center, Greenbelt, MD) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 23, July-Aug. 1986, p. 373-378. Previously cited in issue 17, p. 2471, Accession no. A85-37616. refs

**A87-13098**
**PROTECTIVE COATING FOR THE KU-BAND REFLECTOR**
J. R. DENMAN and L. C. MALDOON (Hughes Aircraft Co., Technology Support Div., Los Angeles) IN: International SAMPE Symposium and Exhibition, 31st, Los Angeles, CA, April 7-10, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 681-692.

Several protective coatings have been tested with a view to selecting a coating system capable of protecting the KU-band antenna reflector used on the Space Shuttle against damage in the low earth orbit (LEO) environment. Of the coatings tested, CV 1144, a flexible room temperature curing silicone coating, has been selected as the best product. This coating system does not affect the operation of the reflector while providing protection against the hostile LEO environment for extended periods. Some test results are presented. V.L.

**A87-16060#**

**RADIATION PROBLEMS IN MANNED SPACEFLIGHT WITH A VIEW TOWARDS THE SPACE STATION**

H. BUCKER and R. FACIUS IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct 4-11, 1986. 9 p.
(IAF PAPER 86-379)

The present discussion endeavors to emphasize the gaps of present knowledge and capabilities which must be closed for an effective and economic realization of a radiation protection concept for manned spaceflight. The usual convention in radiation protection to assume worst case conditions whenever the facts are unknown would unduly compromise the design and construction of the Space Station. This cogently implies the necessity and high priority of a research program to close these gaps. The attached proposals for experiments are directed towards this goal with respect to some of these gaps. Author

**A87-16081#**

**METEOROID AND ORBITAL DEBRIS PROTECTION CONCEPTS**

E. BAUER (ERNO Raumfahrttechnik GmbH, Bremen, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p. refs
(IAF PAPER 86-419)

Meteoroid and orbital debris impacts are an important, design driving requirement of future Space Station elements. For the European Columbus elements, the potential safety requirements as well as the resulting impact particle diameters and velocities are discussed. Major parts of this presentation deal with the general design and verification aspects necessary for the realization of an orbital impact protection system. Additionally, a caution and warning system needed for an immediate determination of the actual impact results is described. The possible repair activities required for maintaining the safety critical space vehicle functions are explained. Author

**A87-17836*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.

**A CONSIDERATION OF ATOMIC OXYGEN INTERACTIONS WITH THE SPACE STATION**

L. J. LEGER and J. T. VISENTINE (NASA, Johnson Space Center, Houston, TX) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 23, Sept.-Oct. 1986, p. 505-511. Previously cited in issue 07, p. 875, Accession no. A85-19773. refs

**A87-18247**

**COLLISIONAL PROBABILITY IN SPACE AND THE DEBRIS ENVIRONMENT IN FUTURE**

K. SATO (Tokyo, University, Japan) and M. NAGATOMO IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 393-398.

The collision of an earth satellite with other orbiting debris is studied to predict the collision probability, using the NASA Satellite Situation Report (1982). To obtain the tendency of number density of debris versus altitude, the lifetime of debris is calculated by the averaging method as a function of the masses of debris and the launch date (on the assumption that each orbit of debris is circular). It is shown that the effect of the periodic solar activity on the number density distribution is significant. The results show that the number of debris continues to increase in the range of altitude between 1000 and 1500 km. Accordingly the collision probability will increase in the same range. Author

**A87-19874*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**PROTECTION OF SOLAR ARRAY BLANKETS FROM ATTACK BY LOW EARTH ORBITAL ATOMIC OXYGEN**

BRUCE A. BANKS, MICHAEL J. MIRTICH, SHARON K. RUTLEDGE, and HENRY K. NAHRA (NASA, Lewis Research Center, Cleveland, OH) IN: Photovoltaic Specialists Conference, 18th, Las Vegas, NV, October 21-25, 1985, Conference Record . New York, Institute of Electrical and Electronics Engineers, Inc., 1985, p. 381-386. refs

The ram impact of low earth orbital atomic oxygen causes oxidation of spacecraft materials including polymers such as polyimides. The rate of oxidation is sufficiently high to potentially compromise the long term durability of Kapton solar array blankets. Ion beam sputter deposited atomic oxygen protective coatings of aluminum oxide, silicon dioxide, and codeposited silicon dioxide with small amounts of polytetrafluoroethylene were evaluated both in RF plasma asher tests and in low earth orbit. Deposition techniques, mechanical properties, and atomic oxygen protection performance are presented. Author

**A87-22659#**

**A SEVERE SPACECRAFT-CHARGING EVENT ON SCATHA IN SEPTEMBER 1982**

H. C. KOONS, P. F. MIZERA, J. L. ROEDER, and J. F. FENNELL (Aerospace Corp., Space Sciences Laboratory, El Segundo, CA) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 6 p. refs
(Contract F04701-85-C-0086)
(AIAA PAPER 87-0475)

Large amplitude electrostatic discharges were detected by the engineering instruments aboard the SCATHA satellite on September 22, 1982. The Pulse Analyzer detected 29 pulses on that date. Seventeen of the pulses exceeded the maximum voltage discrimination level which was set to 7.4 volts. This is the worst instance of electrostatic discharges encountered to date by the SCATHA satellite. Three different spacecraft anomalies occurred on SCATHA on September 22, 1982. The most serious was a two minute loss of data. Data from the Satellite Surface Potential Monitor confirmed that these electrostatic discharges occurred during one of the largest spacecraft charging events recorded by the instruments aboard the SCATHA satellite. Author

**A87-22738*#** Massachusetts Inst. of Tech., Cambridge.

**RADIATION FROM LARGE SPACE STRUCTURES IN LOW EARTH ORBIT WITH INDUCED AC CURRENTS**

D. E. HASTINGS and S. OLBERT (MIT, Cambridge, MA) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 19 p. refs
(Contract NAG3-695)
(AIAA PAPER 87-0612)

Large conducting space structures in low earth orbit will have a nonnegligible motionally induced potential across their structures. The induced current flow through the body and the ionosphere causes the radiation of Alfven and lower hybrid waves. This current flow is taken to be ac and the radiated power is studied as a function of the ac frequency. The current may be ac due either to inductive coupling from the power system on the structure or by active modulation. A Space Station-like structure and tether are studied. For the Space Station structure the radiation impedance is particularly high for frequencies in the tens of kilohertz range which suggests that the Space Station may be efficient source of lower hybrid waves. The tether is also shown to be a generator of VLF waves up to source ac frequencies in the megahertz range. The implications for these two structures are discussed. Author

**A87-27403*** Arizona Univ., Tucson.
**A CCD SEARCH FOR GEOSYNCHRONOUS DEBRIS**
TOM GEHRELS (Arizona, University, Tucson) and FAITH VILAS (NASA, Johnson Space Center, Houston, TX) Icarus (ISSN 0019-1035), vol. 68, Dec. 1986, p. 412-417. NASA-supported research. refs

Using the Spacewatch Camera, a search was conducted for objects in geosynchronous earth orbit. The system is equipped with a CCD camera cooled with dry ice; the image scale is 1.344 arcsec/pixel. The telescope drive was off so that during integrations the stars were trailed while geostationary objects appeared as round images. The technique should detect geostationary objects to a limiting apparent visual magnitude of 19. A sky area of 8.8 square degrees was searched for geostationary objects while geosynchronous debris passing through was 16.4 square degrees. Ten objects were found of which seven are probably geostationary satellites having apparent visual magnitudes brighter than 13.1. Three objects having magnitudes equal to or fainter than 13.7 showed motion in the north-south direction. The absence of fainter stationary objects suggests that a gap in debris size exists between satellites and particles having diameters in the millimeter range. D.H.

**A87-31208#**
**CLEANING UP OUR SPACE ACT**
BRUCE FRISCH Aerospace America (ISSN 0740-722X), vol. 25, Feb. 1987, p. 10, 11.

Space operations have left a significant, and increasing amount, of small debris in orbital slots which are preferred for manned activities. Outgassed material and solid rocket propellant grains can abrade spacecraft windows and degrade optical sensors. A hypervelocity microscopic paint chip once left a 4 mm diam crater in an Orbiter window. Exploding final stages from the Delta and Ariane rockets have left thousands of small pieces in LEO. The number of particles multiplies as collisions occur. NORAD now tracks 6000 pieces of debris in LEO. The problem will be acute for Space Station astronauts in EVA, who will wear new spacesuits with more rigid, impact-resistant parts, and the Space Station, which will have a much larger cross section exposed to, e.g., screws travelling at 10 km/sc. M.S.K.

**N87-10947#** Oak Ridge National Lab., Tenn.
**PROTECTION OF SPACECRAFT FROM METEOROIDS AND ORBITAL DEBRIS**
A. P. FRAAS Mar. 1986 66 p
(Contract DE-AC05-84OR-21400)
(DE86-009996; ORNL/TM-9904) Avail: NTIS HC A04/MF A01

This report presents a review of information on the incidence of meteoroids and solid debris in orbital space, the damaging effects of these materials, and the principles that may be used to design protective shields for orbiting spacecraft. The report was prepared as part of a current Oak Ridge National Laboratory effort to develop and evaluate conceptual designs of space power systems. DOE

**N87-13990*#** Eloret Corp., Sunnyvale, Calif.
**BALLISTIC LIMIT OF 6061 T6 ALUMINUM AND THREAT TO SURFACE COATINGS FOR USE WITH ORBITING SPACE STATION SPACE SUIT MATERIALS**
D. FISH 21 Nov. 1986 29 p
(Contract NCC2-347)
(NASA-CR-179884; NAS 1.26:179884) Avail: NTIS HC A03/MF A01 CSCL 06K

In recent years orbiting satellites, spent components, collisions and explosions have populated the near earth orbit with debris potentially more hazardous than the average meteoroid debris. This new debris has an average density of aluminum (2.78 g/cc) and an average encounter velocity of 10 km/sec. The space station will require many hours of work in this environment and there is concern over hazard to the assembly personnel. A proposed hard suit design utilizes 6061-T6 Aluminum for most of its exposed area. The aluminum surface will be treated for thermal and radiation control. The basic thickness of this suit will be on the order of 1.78 mm (0.070 inches). The selection of 6061-T6 Aluminum for space suits for use on the space station would appear to be worthwhile. The relatively ductile behavior of 6061-T6 aluminum is better than a choice of a more brittle material. F.M.R.

**N87-14386*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**EXAMINATION OF RETURNED SOLAR-MAX SURFACES FOR IMPACTING ORBITAL DEBRIS AND METEOROIDS**
D. J. KESSLER, H. A. ZOOK, A. E. POTTER, D. S. MCKAY, U. S. CLANTON (Department of Energy, Las Vegas, Nev.), J. L. WARREN (Northrop Services, Inc., Houston, Tex.), L. A. WATTS, R. A. SCHULTZ (Purdue Univ., West Lafayette, Ind.), L. S. SCHRAMM (Lockheed Engineering and Management Services Co., Inc., Houston, Tex.), S. J. WENTWORTH et al. *In* NASA. Goddard Space Flight Center Proceedings of the SMRM Degradation Study Workshop p 245-246 1985
Avail: NTIS HC A16/MF A01 CSCL 22B

The thermal insulation of the Solar Maximum Mission launched on 14 February 1980 which consisted of 17 layers of alumized Kapton offers an excellent opportunity to obtain chemistry of impacting particles. To date, approximately 0.7 sq. met. of the insulation and 0.05 sq. met. of the aluminum louvers have been mapped by optical microscope for crater diameters larger than 40 microns. Atomic oxygen has eroded up to 20 microns of the exposed Kapton surfaces removing the older and smaller craters. The crater size distribution found on 3 different Kapton surfaces is shown. About 250 chemical spectra were recorded of particles observed in or around impact pits or in the debris pattern found on the second layer beneath impact holes in the outer layer. The debris populations are listed and discussed. E.R.

**N87-16056#** Massachusetts Univ., Amherst. Dept. of Civil Engineering.
**PARAMETRIC INVESTIGATION OF FACTORS INFLUENCING THE MECHANICAL BEHAVIOR OF LARGE SPACE STRUCTURES Final Technical Report, 1 Nov. 1982 - 30 Jun. 1985**
WILLIAM A. NASH and THOMAS J. LARDNER 30 May 1986 451 p
(Contract AF-AFOSR-0025-83)
(AD-A172880; AFOSR-86-0858TR) Avail: NTIS HC A20/MF A01 CSCL 22B

The investigation has two objectives: (1) To investigate the relative importance of factors such as thermal gradients, differential gravitational effects, solar radiation pressure, albedo effects, and spatial pressure gradients on structural behavior of large space structures; and (2) To investigate structural behavior of a very thin membrane subject to combined internal pressure as well as mechanical and thermal loadings. GRA

**N87-16061#** Oak Ridge National Lab., Tenn.
**SHIELDING OF MANNED SPACE STATIONS AGAINST VAN ALLEN BELT PROTONS: A PRELIMINARY SCOPING STUDY**
R. T. SANTORO, R. G. ALSMILLER, JR., J. M. BARNES, and J. M. CORBIN Sep. 1986 39 p
(Contract DE-AC05-84OR-21400)
(DE87-001586; ORNL/TM-10040) Avail: NTIS HC A03/MF A01

Calculated results are presented to aid in the design of the shielding required to protect astronauts in a space station that is orbiting through the Van Allen proton belt. The geometry considered - a spherical shell shield with a spherical tissue phantom at its center - is only a very approximate representation of an actual space station, but this simple geometry makes it possible to consider a wide range of possible shield materials. Both homogeneous and laminated shields are considered. Also, an approximation procedure - the equivalent thickness approximation - that allows dose rates to be estimated for any shield material or materials from the dose rates for an aluminum shield is presented and discussed. DOE

**N87-18669*#** Boeing Aerospace Co., Seattle, Wash.
**PROTECTIVE COATINGS FOR COMPOSITE TUBES IN SPACE APPLICATIONS**
HARRY W. DURSCH and CARL L. HENDRICKS 1987 12 p
Prepared for presentation at the 3rd International SAMPE Symposium, Anaheim, Calif., 6-9 Apr. 1987
(Contract NAS1-16854)
(NASA-CR-178116; NAS 1.26:178116) Avail: NTIS HC A02/MF A01 CSCL 11B

Protective coatings for graphite/epoxy (Gr/Ep) tubular structures for a Manned Space Station truss structure were evaluated. The success of the composite tube truss structure depends on its stability to long-term exposure to the Low Earth Orbit (LEO) environment with particular emphasis placed on atomic oxygen. Concepts for protectively coating Gr/Ep tubes include use of inorganic coated metal foils and electroplating. These coatings were applied to Gr/Ep tubes and then subjected to simulated LEO environmnet to evaluate survivability of coatings and coated tubes. Evaluation included: atomic oxygen resistance, changes in optical properties and adhesion, abrasion resistancem surface preparation required, coating uniformity, and formation of microcracks in the Gr/Ep tubes caused by thermal cycling. Program results demonstrated that both phosphoric and chromic acid anodized Al foil provided excellent adhesion to Gr/Ep tubes and exhibited stable optical properties when subjected to simulated LEO environment. The $SiO_2$/Al coatings speuttered onto Al foils also resulted in an excellent protective coating. Electroplated Ni exhibited unaccepatble adhesion loss to Gr/Ep tubes during atomic oxygen exposure. Author

**N87-20055*#** Jet Propulsion Lab., California Inst. of Tech., Pasadena.
**SPACE TECHNOLOGY PLASMA ISSUES IN 2001**
HENRY GARRETT, ed., JOAN FEYNMAN, ed., and STEPHEN GABRIEL, ed. 1 Oct. 1986 470 p Workshop held in Pasadena, Calif., 24-26 Sep. 1986 Previously announced in IAA as A87-14943
(Contract NAS7-918)
(NASA-CR-180231; JPL-PUB-86-49; NAS 1.26:180231) Avail: NTIS HC A20/MF A01 CSCL 20I

The purpose of the workshop was to identify and discuss plasma issues that need to be resolved during the next 10 to 20 years (circa 2001) to facilitate the development of the advanced space technology that will be required 20 or 30 years into the future. The workshop consisted of 2 days of invited papers and 2 sessions of contributed poster papers. During the third day the meeting broke into 5 working groups, each of which held discussions and then reported back to the conference as a whole. The five panels were: Measurements Technology and Active Experiments Working Group; Advanced High-Voltage, High-Power and Energy-Storage Space Systems Working Group; Large Structures and Tethers Working Group; Plasma Interactions and Surface/Materials Effects Working Group; and Beam Plasmas, Electronic Propulsion and Active Experiments Using Beams Working Group.

**N87-20063*#** Air Force Geophysics Lab., Hanscom AFB, Mass.
**PLASMA INTERACTIONS WITH LARGE SPACECRAFT**
RITA C. SAGALYN and NELSON C. MAYNARD *In* JPL, Space Technology Plasma Issues in 2001 p 51-68 1 Oct. 1986
Avail: NTIS HC A20/MF A01 CSCL 20I

Space is playing a rapidly expanding role in the conduct of the Air Force mission. Larger, more complex, high-power space platforms are planned and military astronauts will provide a new capability in spacecraft servicing. Interactions of operational satellites with the environment have been shown to degrade space sensors and electronics and to constrain systems operations. The environmental interaction effects grow nonlinearly with increasing size and power. Quantification of the interactions and development of mitigation techniques for systems-limiting interactions is essential to the success of future Air Force space operations. Author

**N87-20064*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
**THE INTERACTION OF SMALL AND LARGE SPACECRAFT WITH THEIR ENVIRONMENT**
URI SAMIR (Michigan Univ., Ann Arbor) and NOBIE H. STONE *In* JPL, Space Technology Plasma Issues in 2001 p 69-91 1 Oct. 1986 Prepared in cooperation with Tel-Aviv Univ., Israel
Avail: NTIS HC A20/MF A01 CSCL 20I

The most significant results from small scientific satellites and from the space shuttle mission STS-3 regarding body-plasma interactions are presented and discussed. The causes for the above information being meager and fragmentary are given. The research avenues to be followed in the future in order to correct this situation are mentioned, including practical ways to achieve this goal. Author

**N87-20079*#** California Univ., San Diego, La Jolla. Center for Astrophysics and Space Science.
**CONTROLLING AND MONITORING THE SPACE-STATION PLASMA INTERACTION: A BASELINE FOR PERFORMING PLASMA EXPERIMENTS AND USING ADVANCED TECHNOLOGY Abstract Only**
ELDEN C. WHIPPLE and RICHARD C. OLSEN (Alabama Univ., Huntsville) *In* JPL, Space Technology Plasma Issues in 2001 p 310 1 Oct. 1986
Avail: NTIS HC A20/MF A01 CSCL 22B

The size, complexity, and motion of space station through the Earth's environmental plasma means that there will be a large, complicated interaction region, involving a sheath, wake, charging of surfaces, induced electric fields, secondary emission, outgassing with ionization, etc. This interaction will necessarily be a factor in carrying out and interpreting plasma experiments and in the use of certain technologies. Attention should be given ahead of time to: (1) monitoring this interaction so that it is well described; (2) implifying the interaction by appropriate design and construction of the spacecraft and by appropriate planning of technology use; and (3) controlling the interaction by both active and passive means. Plasma emitters for modifying and controlling the spacecraft charge should be placed in several locations. Portable electrostatic shields could be deployed around noisy sections of the spacecraft in order to carry out sensitive experiments. A particle umbrella could be raised to deflect the ram ions and neutrals in order to provide a controlled environment. These interactions are briefly discussed. Author

**N87-20080*#** York Univ., Toronto (Ontario). Dept. of Physics.
**SPACECRAFT CHARGING IN THE AURORAL PLASMA: PROGRESS TOWARD UNDERSTANDING THE PHYSICAL EFFECTS INVOLVED Abstract Only**
J. G. LAFRAMBOISE and L. W. PARKER (Parker, Lee W., Inc., Concord, Mass.) *In* JPL, Space Technology Plasma Issues in 2001 p 311 1 Oct. 1986
(Contract F19628-83-K-0028)
Avail: NTIS HC A20/MF A01 CSCL 22B

The work is presented in four parts. First, main differences between the plasma environments in geostationary orbit and low polar orbit with regard to high-voltage charging situations are reviewed. Next, results are presented from a calculation of secondary-electron escape currents from negatively-charged spacecraft surfaces having various orientations relative to the local magnetic-field direction. It is shown that for finite ranges of combinations of electric and magnetic field directions, secondary-electron escape is completely suppressed and therefore cannot help to discharge the spacecraft. In such circumstances, secondary electrons may travel distances many times their gyroradii before reimpacting, and this may produce greatly increased secondary-electron surface currents. Thirdly, a simple rough estimate of the required conditions for high-voltage auroral-zone charging is developed. The results suggest that for any given spacecraft, surface potentials are likely to depend more strongly on the ratio of ambient flux of high-energy electrons to that of all ions, than on any other environmental parameter. Finally, preliminary results are presented of numerical simulation work

directed toward testing this hypothesis. Numerical instabilities encountered in doing this simulation work probably are closely related to physical sensitivities inherent in the physics of the ion wake behind the spacecraft, and especially to beam-like constituents of the ion population in the wake. Author

# 18

# INTERNATIONAL

Includes descriptions, interfaces and requirements of international payload systems, subsystems and modules considered part of the Space Station system and other international Space Station activities such as the Soviet Salyut.

**A87-10044*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**JAPANESE EXPERIMENT MODULE (JEM)**
T. KATO (NASA, Johnson Space Center, Houston, TX; National Space Development Agency of Japan, Tokyo) IN: Space Congress, 23rd, Cocoa Beach, FL, April 22-25, 1986, Proceedings . Cape Canaveral, FL, Canaveral Council of Technical Societies, 1986, p. 7-7 to 7-11.

Japanese hardware elements studied during the definition phase of phase B are described. The hardware is called JEM (Japanese Experiment Module) and will be attached to the Space Station core. JEM consists of a pressurized module, an exposed facility, a scientific/equipment airlock, a local remote manipulator, and experimental logistic module. With all those hardware elements JEM will accommodate general scientific and technology development research (some of the elements are to utilize the advantage of the microgravity environment), and also accommodate control panels for the Space Station Mobile Remote Manipulator System and attached payloads. Author

**A87-10549**
**THE COMMUNICATIONS 'BLACK SPOTS'**
R. G. HATHAWAY (Marconi Secure Radio Systems, Ltd., Portsmouth, England) British Interplanetary Society, Journal (Space Technology) (ISSN 0007-084X), vol. 39, Aug. 1986, p. 372-375.

Polar orbiting platforms can bring a new communications service to the Arctic and Antarctic regions. At latitudes above 65 deg communications became less efficient and at 70 deg distinctly difficult in terms of reception for both voice and video. A benefit of a polar orbiting platform is its communications possibilities for around the poles, or the 'black caps' in communication terms. At a height of 500 km the time available for transmission/receiving can be made up to 20 min in a 90 orbit period. The shortest viewing time would be about 12 min sufficient for a 2 hr video using a 10:1 compression ratio. The great advantage of a low earth orbit (up to 100 km) is the reduction in path loss. At 500 km the loss is approximately 30 dB less than that resulting from operation with a geostationary satellite. A much reduced path loss allows the use of modest EIRPs on both the platform and the ground terminals, the latter of which could be developed using Inmarsat II technology. Author

**A87-10901**
**VIBRATION DATA REDUCTION FOR DESIGN, ANALYSIS AND TESTING OF SPACECRAFT**
P. S. NAIR, M. SAMBASIVA RAO (Indian Space Research Organization, Satellite Centre, Bangalore, India), and S. DURVASULA (Indian Institute of Science, Bangalore, India) IN: Finite elements in computational mechanics - FEICOM '85; Proceedings of the International Conference, Bombay, India, December 2-6, 1985. Volume 2 . Oxford, Pergamon Press, 1985, p. 677-688. refs

Techniques for reducing the vibrational data produced by current FEM programs for large spacecraft structures are developed analytically and demonstrated. It is shown that the dynamical behavior of a structure can be understood by deriving the modal effective mass, the effective inertance or flexibility, and the energy distribution from the FEM data, processes involving relatively small computational effort. Numerical results for two sample problems (a simple cantilever beam and the APPLE spacecraft - mounted between Meteosat and CAT as in the Ariane composite payload stack) are presented in tables and graphs and briefly characterized. The reduction techniques are shown to be quite effective in sorting the FEM data for interpretation by the designer. T.K.

**A87-11349**
**MANUFACTURING IN SPACE: PROCESSING PROBLEMS AND ADVANCES**
V. S. AVDUEVSKII, S. D. GRISHIN, L. V. LESKOV, V. V. SAVICHEV, and V. T. KHRIAPOV (Tekhnicheskie i Tekhnologicheskie Problemy Kosmicheskogo Proizvodstva, Moscow, Izdatel'stvo Mir, 1985) Moscow, Mir Publishers, 1985, 248 p. Translation. refs

A systematic analysis of the experimental studies into space manufacturing conducted in the USSR is presented. Technological experiments, and space systems and equipment for space manufacturing are discussed. Experimental studies related to the preparation of electronic materials, space metallurgy, glass manufacturing, and space biotechnology are described. Experiments designed to analyze the effects of weightlessness on the physical features of processes are examined. The transportation and power generating system for space manufacturing is considered. I.F.

**A87-11384**
**FABRICATION OF A CARBON FIBRE/ALUMINIUM ALLOY COMPOSITE UNDER MICROGRAVITY**
Y. MISHIMA, M. HORI, T. SUZUKI, and S. UMEKAWA (Tokyo Institute of Technology, Yokohama, Japan) Journal of Materials Science (ISSN 0022-2461), vol. 21, Aug. 1986, p. 2763-2766. Research supported by the National Space Development Agency of Japan and Science and Technology Agency. refs

Fabrication of a composite material with ultralow density and high stiffness under microgravity is the objective of the present investigation. The composite structure to be obtained is a random three-dimensional array of high modulus, short carbon fibers bounded at contact points by an aluminum alloy coating on the fibers. The material is highly porous, and thus has a very low density. The motivation toward the investigation, simulation experiments, choice of the component materials, and in-flight experiment during ballistic trajectory of a National Space Development Agency rocket, are described herein. Supporting experimental evidence shows that the cohesion between the carbon fiber and the aluminum alloy is excellent, by which the achievement of desired properties of such composites seems probable. Author

**A87-12086**
**ON THE INITIATION OF SPS DEVELOPMENT**
K. KURIKI (Tokyo, University, Japan) (University of Tokyo, Institute of Space and Astronautical Science, Space Energy Symposium, 4th, Tokyo, Japan, Mar. 1, 1985) Space Solar Power Review (ISSN 0191-9067), vol. 5, no. 4, 1985, p. 315-320.

The concept of finite time availability, a new idea of thermodynamics, is applied to decisions on when the development of the solar power satellite (SPS) should be initiated and how long a lead time should be taken. Admitting the errors in estimation of parameters, an earlier start is concluded to be much safer than a delayed start. Author

**A87-12087**

**A SMALL SPACE PLATFORM SYSTEM - POSSIBLE PRECURSOR OF SEEL**

M. NAGATOMO, J. ONODA, I. NAKATANI, K. KURIKI, A. USHIROKAWA (Tokyo, University, Japan) et al. (University of Tokyo, Institute of Space and Astronautical Science, Space Energy Symposium, 4th, Tokyo, Japan, Mar. 1, 1985) Space Solar Power Review (ISSN 0191-9067), vol. 5, no. 4, 1985, p. 321-332.

The Space Flyer Unit (SFU) is a free-flying platform to be carried by the Space Shuttle Orbiter. The SFU functions between the experiments on board the platform and the Orbiter as a single interface of electrical and mechanical systems. The platform will accommodate experimental instruments in standard payload boxes as well as on the external structure if they are too large to be installed in a box. Experiments in each payload box will be provided with electrical power, telemetry and command service from CDMS of the platform and/or the Orbiter or the ground station. An operator on board the Orbiter can interact with the experiments via the platform CDMS. The SFU is smaller than the bus platform which is supposed to be used by the Space Energetic and Environmental Laboratory (SEEL), but similar operational capability is expected. Some preliminary experiments for the SEEL will be carried out with a combination of several experimental instruments. For example, the high-voltage solar power test will be used for an electrical propulsion test. Space structure experiment can be applied to the advanced technology development for the SEEL.
Author

**A87-12089**

**2-D ARRAY EXPERIMENT ON BOARD A SPACE FLYER UNIT**

K. MIURA and M. NATORI (Tokyo, University, Japan) (University of Tokyo, Institute of Space and Astronautical Science, Space Energy Symposium, 4th, Tokyo, Japan, Mar. 1, 1985) Space Solar Power Review (ISSN 0191-9067), vol. 5, no. 4, 1985, p. 345-356. refs

The purpose of this paper is to describe the 2-D array system and its experiment mission on board a space flyer unit. The term '2-D array' means the two-dimensionally deployable array, and the 2-D array system consists of a large planar array blanket and structural compressive members that support it. The main object of this experiment is the verification in space of the effectiveness of tension stabilized large planar space structures. Possible applications include a large solar array, a solar sail, a space radar and a space VLBI.
Author

**A87-12852**

**THE VIABILITY AND THE MUTABILITY OF PLANTS AFTER SPACE FLIGHT [ZHIZNESPOSOBNOST' I MUTABEL'NOST' RASTENII POSLE KOSMICHESKOGO POLETA]**

E. N. VAULINA, I. D. ANIKEEVA, and L. N. KOSTINA IN: Microorganisms in artificial ecosystems . Novosibirsk, Izdatel'stvo Nauka, 1985, p. 5-11. In Russian. refs

The effect of space-flight conditions on the postflight viability, growth rate, and mutability of seeds and plants was investigated, using seeds and plants of Crepis capillaris and Arabidopsis thaliana carried aboard Salyut-6 and Salyut-7 Space Stations. Dry seeds, sprouts, and plants in different phases of development were examined after 49, 201, 226, 408, and 827 flight days, using seed germination, the frequency and the chromosomal aberration spectra in the root meristem, the rate of plant death at different growth stages, plant fertility, and the recessive mutation frequency as criteria of the viability mutability of the affected plants. The respective characteristics were compared with those of plants on the ground. The prolonged storage under both land and space conditions was found to decrease the germination ability, the survival rate, and the fertility, and to increase the number of mutations, but the effects of space storage were significantly more adverse. The effects of space flight are considered to be caused by the mutagenicity of cosmic rays as well as by the reduced chromosomal repair capacity.
I.S.

**A87-12854**

**MODIFICATION BY ALPHA-TOCOPHEROL OF THE MUTATIONAL PROCESS IN THE SEEDS OF THE WELSH ONION SUBSEQUENT TO A PROLONGED SPACE FLIGHT [MODIFIKATSIIA ALPHA-TOKOFEROLOM MUTATSIONNOGO PROTSESSA V SEMENAKH LUKA-BATUNA, PERENESSHIKH DLITEL'NYI KOSMICHESKII POLET]**

A. A. ALIEV, U. K. ALEKPEROV, A. L. MASHINSKII, I. T. ASKEROV, D. D. AKHUNDOVA et al. IN: Microorganisms in artificial ecosystems . Novosibirsk, Izdatel'stvo Nauka, 1985, p. 15-19. In Russian. refs

The effect of alpha-tocopherol on cytogenic activity and mutability was studied in seedlings of Welsh onion after the dry seeds were flown aboard the Salyut-7 Space Station or stored on land. Subsequent to the 522-day flight, the seeds from the two batches were soaked either in water or in a 0.01 microgram/ml solution of alpha-tocopherol, and the seedlings were fixed 65 h later. Compared with the level of chromosomal aberrations found at the start of the experiment, the levels of aberrations in the root meristem of the seedlings grown in water from either land-aged or space-flight-aged seeds were found to be significantly elevated. On the other hand, in the seedlings grown in the tocopherol solution the numbers of aberrations were at the initial, prestorage, levels. In addition, alpha-tocopherol was found to stimulate the mitotic activity of all seeds.
I.S.

**A87-12856**

**ULTRASTRUCTURE OF THE ROOT CAP OF ARABIDOPSIS PLANTS UNDER NORMAL CONDITIONS AND UNDER HYPOGRAVITY [UL'TRASTRUKTURA KORNEVOGO CHEKHLIKA RASTENII ARABIDOPSISA V NORME I V USLOVIIAKH GIPOGRAVITATSII]**

V. A. TARASENKO IN: Microorganisms in artificial ecosystems . Novosibirsk, Izdatel'stvo Nauka, 1985, p. 23-29. In Russian. refs

Structural changes caused by hypogravity were observed, using TEM, in plants of Arabidopsis thaliana grown either in a horizontal clinostat (at 2 rpm) or aboard the Salyut-6 Space Station. Compared to the ground-grown controls, plants grown in the clinostat exhibited different distributions of the amyloplasts, smaller starch granules, an increase in vacuolation. These changes were intensified in the plants grown aboard the Space Station, which exhibited intensive vacuolation, an almost total absence of starch granules, and an appearance of zones of lysis in the cytoplasm and in cellular membranes. On the other hand, the mitotic processes in the root cap meristem were not affected. It is suggested that the observed structural changes in the space-grown plants were caused by the combined effects of weightlessness and the subsequent transfer to terrestrial gravity conditions.
I.S.

**A87-12863**

**SUBMICROSCOPIC ORGANIZATION OF CHLORELLA CELLS GROWING FOR NINE DAYS ABOARD SALYUT-6 [SUBMIKROSKOPICHESKAIA ORGANIZATSIIA KLETOK KHLORELLY, RASTUSHCHIKH V TECHENII 9 SUT NA BORTU NOS 'SALIUT-6']**

A. F. POPOVA, E. L. KORDIUM, and G. S. NECHITAILO IN: Microorganisms in artificial ecosystems . Novosibirsk, Izdatel'stvo Nauka, 1985, p. 66-71. In Russian. refs

Cultures of the LARG-1 strain of Chlorella vulgaris were grown for nine days aboard Salyut-6, and the ultrastructural features and the developmental characteristics of the plant cells were examined after landing. The submicroscopic organization of cells exposed to the conditions of space flight did not differ significantly from the controls grown on land. The only differences were some vacuolation and slight variations of cytokinesis, as well as diminished contents of stored polysaccharides in space-grown cells.
I.S.

**A87-12866**

**COMPARISON OF THE CHARACTERISTICS OF ALGAL GROWTH IN WEIGHTLESSNESS USING LIVE AND FIXED BIOLOGICAL MATERIAL [SRAVNITEL'NAIA KHARAKTERISTIKA ROSTA VODOROSLEI V NEVESOMOSTI PO ZHIVOMU I FIKSIROVANNOMU BIOLOGICHESKOMU MATERIALU]**

V. N. SYCHEV, T. B. GALKINA, E. M. KONDRATEVA, and T. G. GAVRISH IN: Microorganisms in artificial ecosystems . Novisibirsk, Izdatel'stvo Nauka, 1985, p. 85-87. In Russian.

**A87-13067**

**SPACE MATERIALS IN EUROPE**

J. DAUPHIN (ESA, Materials Section, Noordwijk, Netherlands) IN: International SAMPE Symposium and Exhibition, 31st, Los Angeles, CA, April 7-10, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 276-290. refs

A comprehensive evaluation is made of the development status of materials for such space structures as those of satellites and space probes that have been constructed under the aegis of the ESA. Attention is given to the performance criteria for which spacecraft materials that will be subjected to ionizing radiation, temperature extremes and vacuum (potentially outgassing) conditions must be qualified. The organizational details of product assurance and approval procedure management are also presented. Representative of advanced materials-employing spacecraft are the Marecs maritime satellite, the Giotto Halley comet probe, and the Space Telescope's solar array; these respectively employ a carbon fiber-reinforced aluminum honeycomb antenna, a 'Sepcarb' carbon/carbon composite rocket nozzle, and novel silicone adhesives. O.C.

**A87-13947**

**SOVIET STRIDES - AMERICAN LAUNCHERS ARE GROUNDED, BUT THE USSR PROGRAM COULDN'T BE HEALTHIER**

J. W. ANDERSON Commercial Space (ISSN 8756-4831), vol. 2, Summer 1986, p. 26, 27; 29, 31.

The current status of the US-Soviet 'Great Space Race' is assessed. While NASA has been faced with the many obstacles arising from the Shuttle, Delta, and Titan programs, it is believed that the Soviet shuttle will make its first flight by early 1987. With easy access to space, Soviet work in materials processing in space is moving closer to operational levels due to their extensive research aboard the Salyut series of stations and the Mir. It is noted that the Soviet Union puts its money in space station technology while US dollars have focused on the Shuttle, design development for the US Space Station and initial research efforts for the Strategic Defense Initiative. The feasibility of joint missions to Mars is discussed. K.K.

**A87-14053#**

**TETHERED SATELLITE SYSTEM (TSS) CORE SCIENCE EQUIPMENT**

C. BONIFAZI (CNR, Rome, Italy) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 23 p. refs

The main requirements for the tethered satellite system (TSS) electrodynamic mission which is to investigate the interaction in the ionosphere, are described. The TSS is designed to allow satellites of up to 500 Kg to be tethered upward or downward from the Orbiter up to distances of 100 km. The tether current-voltage control system for conducting the tether and the three-axis accelerometer-gyro system for assessing dynamic perturbations are required for the electrodynamic mission. I.F.

**A87-14063#**

**THE RETE AND TEMAG EXPERIMENTS FOR THE TSS MISSIONS**

M. CANDIDI, M. DOBROWOLNY (CNR, Istituto di Fisica dello Spazio Interplanetario, Frascati, Italy), and F. MARIANI (Roma II, Universita, Rome, Italy) NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986, Paper. 10 p. refs

The purpose of the following presentation is to illustrate the measurements to be performed by the RETE (Research on Electrodynamic Tether Effects) and TEMAG (TEther MAGnetometer) experiments on board the Tethered Satellite. They will measure locally waves and fields around the satellite. The instruments' main characteristics are outlined with reference to the peculiar environment to be investigated. Justification of the experiments' sensitivities is given with respect to the main scientific objectives to be pursued. da

**A87-14820**

**COSMONAUTS HAVE THE RIGHT STUFF, TOO - A CONVERSATION WITH VLADIMIR DZHANIBEKOV**

M. S. HILLYER Space World (ISSN 0038-6332), vol. W-9-273, Sept. 1986, p. 17-20.

Vladimir Alexandrovich Dzhanibekov, one of the Soviet Union's most experienced cosmonauts, is a verteran of five space missions and two space walks. All five missions included docking with Salyut orbital stations. An account is given of the technical problems which required manual attention during the Soyuz T-6 and T-13 missions, rendezvous techniques, health related matters, and undertakings planned for the future. K.K.

**A87-15389**

**JAPAN'S PARTICIPATION IN THE SPACE STATION PROGRAM**

Y. MORISHITA (National Space Development Agency of Japan, Tokyo) and N. HARA (National Space Development Agency of Japan, Los Angeles, CA) IN: Space Station beyond IOC; Proceedings of the Thirty-second Annual International Conference, Los Angeles, CA, November 6, 7, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 147-151.
(AAS PAPER 85-487)

The development work of the Japanese Experiment Module (JEM) is now being conducted by NASDA as the phase B study of the Japanese participation in the U.S. Space Station Program. The summary of JEM IOC and its evolution are described here. At this moment the driving factors of JEM evolution are mission candidates which are collected from various fields in Japan but not incorporated in JEM IOC, weighting its feasibility and cost performance aspect. Real JEM evolution may, however, have a completely different configuration as it is hopefully expected that the new mission candidates will be created through the development work of JEM IOC, especially in the discussion of international cooperation and Japanese role for the Space Station. Author

**A87-15390**

**INTERNATIONAL COOPERATION IN THE SPACE STATION ERA**

T. H. USSHER (Spar Aerospace, Ltd., Remote Manipulator Systems Div., Weston, Canada) IN: Space Station beyond IOC; Proceedings of the Thirty-second Annual International Conference, Los Angeles, CA, November 6, 7, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 153-159.
(AAS PAPER 85-488)

Various ways in which the Space Station will be an international effort are discussed, with an emphasis on Canadian participation in the program. Prime reasons nations are joining the program include technology exchanges, a refinement of management procedures, expansion of the knowledge base and the creation of jobs. Canada, developer of the RMS, is designing an Integrated Servicing and Test Facility, building on the experience with robotics, and pushing the bounds of expert systems and AI. M.S.K.

**A87-15806#**
**RENDEZVOUS AND DOCKING VERIFICATION AND IN-ORBIT DEMONSTRATION**
P. P. NGUYEN (Aerospatiale, Paris, France), W. FEHSE (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands), A. GETZSCHMANN (MBB/ERNO, Bremen, West Germany), and B. CLAUDINON (Matra, S.A., Velizy-Villacoublay, France) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 19 p. refs
(IAF PAPER 86-07)
A novel, autonomous rendezvous and docking (RVD) concept is under development in Europe with a view to application in manned vehicles. The system encompasses navigation and guidance sensors, docking/berthing mechanism hardware, and onboard processors and software. The software is responsible for guidance and navigation intelligence, trajectory and attitude control, and control mode sequencing logic. Attention is given to a verification mission involving two Eureca platforms, one of which is deployed and the other retrieved during a Space Shuttle flight. O.C.

**A87-15808#**
**NAVIGATION, GUIDANCE, RENDEZ-VOUS AND DOCKING - ACTIVITIES CARRIED OUT FOR COLUMBUS BY THE FLIGHT OPERATIONS ORGANIZATION**
A. BURATTI IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p.
(IAF PAPER 86-09)
Orbit and attitude optimization and control are examined. The routine orbit is affected by the transfer orbits and the maneuvers required for each experiment; additional factors which must be considered in order to select proper operating orbits are discussed. Two orbits were selected for Columbus: the International Space Station orbit with an altitude of 463 km and an inclination of 28.5 deg and the polar sun-synchronous orbit with an altitude of 850 km and an inclination of 98.8 deg. It is observed that ESA S-band stations provide good accuracy for navigating the polar platform and the TDRSS will be used for communication on Columbus. I.F.

**A87-15809#**
**AUTOMATION AND ROBOTICS IN THE FUTURE GERMAN SPACE PROGRAM**
P. P. CHANDLER (DFVLR, Cologne, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 5 p.
(IAF PAPER 86-11)
The results of a study of the role of advanced automation and robotics (A&R) in several key areas of the future German space program are reported. The principal topics of the study are: (1) A&R for the D-2 Spacelab mission and follow-ons; (2) application of automation to space systems; (3) ground-based A&R test beds; and (4) A&R possibilities for the Columbus program. It is emphasized that A&R is essential not only for manned space activities but also for extended micro-G research and, eventually, space production. V.L.

**A87-15813#**
**GIOTTO - THE MISSION OPERATIONS SYSTEM**
D. E. B. WILKINS (ESA, European Space Operations Centre, Darmstadt, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 12 p. refs
(IAF PAPER 86-19)
The design and the principal components of the Mission Operating System developed for the support of the Giotto mission to Halley's comet are reviewed. Some of the new systems developed under this program include: the Deep Tracking System for measuring the range and range rate of Giotto from the earth, MASER receiving system, the High Performance Demodulator, the Reed-Solomon/Vitterbi Decoder, S-band/X-band Antenna Feed, and Packet Communications System operating at CCITT X-25 Protocol. V.L.

**A87-15823#**
**THE COLUMBUS SYSTEM - OBJECTIVES AND DESIGN**
F. LONGHURST, J. GRAF, G. BOLTON (ESA, European Space Technology Centre, Noordwijk, Netherlands), J. MAJUS (DFVLR, Cologne, West Germany), and W. WIENSS (MBB/ERNO, Bremen, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 13 p.
(IAF PAPER 86-33)
The objectives and design of Europe's Columbus system, projected for use in the future International Space Station system, are presented. The Columbus system consists of four elements: (1) pressurized four-segment laboratory module for permanent attachment to the Space Station; (2) a polar platform for the morning orbit; (3) a small coorbiting platform (based on the Eureca platform); and (4) a man-tended free flyer configuration consisting of two-segment pressurized module together with an unmanned resource module. I.S.

**A87-15824#**
**THE COLUMBUS DATA MANAGEMENT SYSTEM**
P. JOURDAN, X. LABORDE, and P. PITARD (Matra, S.A., Toulouse, France) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p.
(IAF PAPER 86-36)
The design constraints applied to the on-board Data Management System (DMS) of the European Columbus space segment are discussed, as are the key features of the system. The DMS architecture is examined with particular reference to the manned system, maintenance in space, system evolvability, commonality, autonomy, information security and privacy, and standards accommodation. The main concepts underlying the DMS architecture are the distributed system concept, layered software, and fault tolerance. The discussion covers a description of the principal DMS subsystems. V.L.

**A87-15825#**
**THE EVOLUTION OF A SERVICEABLE EURECA**
J. WEYDANDT, H. P. RICHARZ, H. WARTENBERG, and L. KERSTEIN (MBB/ERNO, Bremen, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 13 p. refs
(IAF PAPER 86-38)
The European retrievable carrier, 'Eureca', is a ground-based platform for short microgravity missions whose development into a serviceable platform for longer scientific missions is presently considered. After providing an advanced space-based platform design for increased payload demands, attention is given to platform adaptation for a variety of scientific missions and servicing operations. The prospects for cost-effective utilization of different platform types on the basis of novel operational concepts is analyzed by parametric life cycle cost calculations for different payloads and mission scenarios. O.C.

**A87-15827#**
**THE MAN-TENDED SERVICING UNIT - A USEFUL SUPPLEMENT TO EXTRA-VEHICULAR ACTIVITIES**
L. BASILE (Aeritalia S.p.A., Turin, Italy), U. HILZENBECHER (Dornier System GmbH, Friedrichshafen, West Germany), D. KASSING (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands), and J. C. VANNIER (Aerospatiale, Les Mureaux, France) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 21 p.
(IAF PAPER 86-40)
Results of a study of the concept of a Man-Tended Servicing Unit (MTSU), a small pressurized maneuverable vehicle equipped with an advanced service manipulator system which could supplement EVA in future missions, are summarized. The vehicle is operated by an astronaut in a 'shirt sleeve' environment which also provides sufficient protection against space radiation; MTSU missions will be carried out in the vicinity of its space base. The general design and functional capabilities of the Octopus, an MTSU for the Columbus and Hermes programs, are examined. V.L.

**A87-15828#**
**SOME ASPECTS OF THE SALYUT-7/MIR STATION OPERATIONS**
IU. P. SEMENOV and V. P. LEGOSTAEV IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 14 p.
(IAF PAPER 86-41)

The operational features of Salyut-7 and Mir, in coplanar orbits, are discussed. Special attention is given to the design and functions of Mir, a new-generation space station launched in February 1986 which will serve as a base for a multipurpose permanent orbital complex to be constructed in orbit. The most important difference of the Mir from its precursors is its radio engineering complex, which provides communication with ground stations via a relay satellite. I.S.

**A87-15830#**
**THE EUROPEAN UTILIZATION PROGRAMME FOR THE SPACE STATION**
F. UNZ (DFVLR, Cologne, West Germany) and G. OELKER (Aeritalia S.p.A., Turin, Italy) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p.
(IAF PAPER 86-45)

European programs related to the utilization of the Space Station, in particular the Columbus payload and utilization studies, are discussed. The payload studies are concerned with investigations in the areas of life sciences, material sciences, fluid physics, astronomy, solar terrestrial physics, earth observation, communications and navigation, and new technologies, and the pressurized module, polar platform, and coorbiting platform are examined in the utilization program. The proposed use of the European Laboratory is described. Examples of model payloads are presented. I.F.

**A87-15831#**
**JAPANESE EXPERIMENT MODULE (JEM) BASIC OPERATION CONCEPT**
Y. OHKAMI (National Aerospace Laboratory, Chofu, Japan), N. IWASAKI, and K. HIGUCHI (National Space Development Agency of Japan, Tokyo) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 7 p.
(IAF PAPER 86-46)

The basic operations concept of the JEM is described. The on-board JEM is to consist of a pressurized module, an exposed facility, a scientific/equipment air lock, a remote manipulator, and an experiment logistic module. The ground support for the system is to include a JEM logistics system, training and simulation facilities, and launch site operation. Potential launch and return systems for crew and payloads, and the module's communication network are examined. I.F.

**A87-15833#**
**SERVICING OF THE FUTURE EUROPEAN STATIONS/PLATFORMS THROUGH EUROPEAN MEANS**
P. EYMAR, Y. PEYRIN (Aerospatiale, Les Mureaux, France), C. COUGNET (Matra, S.A., Toulouse, France), P. BRUDIEU, and P. DUTTO (CNES, Toulouse, France) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 16 p. refs
(IAF PAPER 86-48)

The payload capability of the projected ESA Hermes spaceplane allows efficient quarterly servicing of either the Columbus component of the NASA Space Station or an autonomous European space station, with a crew of two. Larger space station systems will require the use of an additional servicing system, such as Ariane 5. Attention is given to the effect of Space Station orbit choice on serviceability. O.C.

**A87-15840#**
**INTERNATIONAL COMMONALITY FOR SPACE STATION**
W. P. FEDOR, R. D. WAISS (Boeing Aerospace Co., Seattle, WA), and M. BAUNE (ERNO Raumfahrttechnik GmbH, Bremen, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 12 p.
(IAF PAPER 86-61)

The benefits possible with a single standard laboratory module design for the Space Station are examined. Examples of previous international cooperation projects such as the Spacelab and ESA Ariane programs are discussed. An international commonality approach to the Space Station program needs to establish a commonality-standardization program at the onset and to define the procedures, requirements, and hardware which can be easily standardized. The development of a common sized module, standard operational procedures, common hardware and software, and standard drawing, title blocks, and numbering systems is considered. I.F.

**A87-15842#**
**AN ORBITAL REFUELING SYSTEM FOR THE ESA COLUMBUS SPACE STATION**
J. KOWALEK (ERNO Raumfahrttechnik GmbH, Bremen, West Germany) and W. BERRY (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 14 p.
(IAF PAPER 86-63)

Phase 1 of an ESA study of orbital refueling capabilities for Columbus has derived general requirements, identified candidate concepts, and selected an optimal concept that involves transfer by way of fluidic and electrical connectors that are integral with a spacecraft docking adaptor. Key design features encompass electrical pump transfer of propellants, recovery and recompression of gaseous pressurant by an electrical compressor, fully automatic refueling by means of microprocessor controllers, and a human supervision/intervention capability. O.C.

**A87-15843#**
**SHORT RANGE AND PROXIMITY SENSOR FOR AUTONOMOUS RENDEZ-VOUS AND DOCKING**
S. FLAMENBAUM, T. BOMER (Matra, S. A., Velizy-Villacoublay, France), J. JAMET, P. TURON, and J. P. KREBS (Societe Anonyme d'Etudes et Realisations Nucleaires, Limeil-Brevannes, France) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 13 p.
(IAF PAPER 86-64)

Rendezvous and docking (RVD) sensors have currently been the subject of investigation on the part of MATRA and SODERN. The paper presents the 'future flight sensor' together with estimates of accuracy, mass, power, and reliability. The imager sensor for the short range and proximity phases of RVD appears to be the most suitable and promising in terms of performance capability. Moreover, this concept conforms to the present-day Columbus and Hermes specifications. Author

**A87-15846#**
**MEMORIES FOR COLUMBUS DATA MANAGEMENT SYSTEM**
F. PITTERMANN and F. J. ROMBECK (Dornier System GmbH, Friedrichshafen, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p.
(IAF PAPER 86-67)

Various memory types for the Columbus data management system are described. The data handling system memories are used for format buffering in payloads and as telemetry buffers to overcome telemetry link noncoverage; the functions to be performed by the memories on Columbus are discussed. Consideration is given to fast/small memories, medium speed and large capacity read and write memories, medium speed and large capacity random block access read only memory, and fast/medium speed serial recorder memory. The applications of semiconductor memories, magnetic bubble memory, magnetic tape recorder,

magnetic disk memory, and optical laser disks to the data management system are studied. I.F.

**A87-15855#**

**R-MOMS, THE RADARSAT MODULAR OPTOELECTRONIC MULTISPECTRAL SCANNER - A POTENTIAL CANDIDATE FOR POP ALSO**

D. MEISSNER (Messerschmitt-Boelkow-Blohm GmbH, Ottobrunn, West Germany) and H. L. WERSTIUK (Canadian Department of Communications, Communications Research Centre, Ottawa, Canada) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p.
(IAF PAPER 86-81)

Results of the Phase B study for R-MOMS (an optical sensor designed to give additional spectral information during daylight) on a long term RADARSAT mission are summarized. R-MOMS will consist of four spectral channels with the center wavelengths at 485, 555, 650 and 825 nm. R-MOMS will employ the same double-lens principle as MOMS-01 except that the number of usable pixels will be increased up to 13,500. K.K.

**A87-15874#**

**ARIES - THE EXTENSION OF ARIANE 5 CAPABILITIES TO ORBITAL TRANSFER**

P. MOLETTE, C. COUGNET (Matra S.A., Toulouse, France), and P. GROEPPER (ERNO Raumfahrttechnik GmbH, Bremen, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 13 p.
(IAF PAPER 86-111)

A review of the potential missions requiring Aries leads to the identification of three classes of Aries missions; they differ by the level of involvement of Aries in the rendezvous operations. This paper describes the Aries overall configuration, and discusses the modifications brought to the standard L5 and Ariane-5 Vehicle Equipment Bay (VEB) to allow them to fulfill the various mission requirements. Thus, with minor impacts on the basic VEB/L5, it is possible to define additional kits of equipments to be implemented either on the VEB or on the payload adaptor to meet the mission requirements. Author

**A87-15876#**

**COLUMBUS SERVICE VEHICLE AND DERIVATIVES**

P. EYMAR (Aerospatiale, Division Systemes Balistiques et Spatiaux, Paris, France) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p.
(IAF PAPER 86-113)

When Columbus phase B1 started in early 1985 the Service Vehicle (SV) was one of the four candidate elements to be developed by Europe in the frame of the U.S. Space Station program. The present paper will briefly summarize the main results achieved on the SV after phase B1 completion. It will also provide data on some SV derivatives which are currently under study, and particularly one resulting actually from an adaptation of this SV to a more European autonomous environment relying exclusively upon the use of Ariane and Hermes launchers: the so-called Ariane Transfer Vehicle (ATV). An other derivative is an answer to the manned space interventions issue, an intermediate concept betwen a manned SV and an astronaut with its ancilliary devices (e.g. Manned Maneuvering Unit). Author

**A87-15877#**

**FEASIBILITY OF AN ORBIT TRANSFER VEHICLE TO BE USED FOR COLUMBUS ELEMENTS**

G. BORRIELLO, A. FABRIZI (SNIA BPD S.p.A., Colleferro, Italy), and F. ROSSI (CNR, Rome, Italy) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p. refs
(IAF PAPER 86-114)

The paper presents the results of a commonality analysis which has been performed based on the latest Man Tended Free Flyer (MTFF) and Platform (PF) propulsion requirements and design. The intent was to evaluate and check the feasibility of a common Orbit Transfer Vehicle to be used for both the Columbus Elements. Naturally not only the propulsion subsystem but also the structure and thermal control of the modules have been studied. The study has shown the practicability of a module which can be adapted to the needs of MTFF and PF with minimum changes, but the acceptability of the penalties due to foreseen requirements changes versus cost savings still needs to be evaluated at the overall elements level. Author

**A87-15883#**

**THE FUNCTIONAL ARCHITECTURE OF THE HERMES SYSTEM**

M. SAINZ (Matra, S.A., Centre Spatial de Toulouse, France) and D. DASSAUD (CNES, Toulouse, France) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p.
(IAF PAPER 86-126)

This paper describes an approach to Hermes functional system architecture definition. After an induction of the Hermes system, the Hermes cycle is broken down into phases. An allocation of the operational architecture modes is presented along with the Hermes operations cycle. Five major constraints are extracted from the analysis of the operations plan leading to the definition of a functional general architecture of the system. It allows one to address key organization factors without being impaired by detailed design choices. Author

**A87-15893#**

**SOLAR ARRAY MECHANISMS FOR INDIAN SATELLITES, APPLE, IRS AND INSAT-IITS**

S. DAS (Indian Space Research Organization, Vikram Sarabhai Space Centre, Trivandrum, India) and I. SELVARAJ (Indian Space Research Organization, Satellite Centre, Bangalore, India) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 12 p.
(IAF PAPER 86-142)

Large-area rigid panel deployable and trackable solar arrays are widely used in the present day operational satellites. Three solar array mechanisms of this type for Indian spacecrafts are described, one of which has already undergone flight verification. The other two mechanisms are of higher complexity and are being readied for launch in the immediate future, as essential for providing the country's space services in communication and remote sensing fields. The design approach, test program and implications of test modeling towards achieving the design goal are discussed. Performance characteristics of the solar array mechanisms achieved after flight verification and qualification tests are also highlighted in the paper. Author

**A87-15896#**

**SOLAR DYNAMIC POWER SUPPLY FOR ORBITING SYSTEMS WITH FREE-PISTON STIRLING ENGINE**

H. KUCZERA (ERNO Raumfahrttechnik GmbH, Ottobrunn, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p.
(IAF PAPER 86-145)

Solar thermal dynamic space power systems represent an attractive alternative for solar photovoltaic systems. The Stirling cycle has been extensively developed and tested for various terrestrial applications. It is therefore believed that a free piston Stirling engine with an integrated linear alternator will have sufficient potential for space power applications. A solar dynamic system for about 1 kWe has been proposed for the second German Spacelab mission (D2) in 1990 and is further being considered as a candidate for similar flight opportunities. This might be the very first in-orbit operation of a free piston Stirling engine. The actual power system configuration and operating characteristics will mainly be determined by the particular mission constraints. This paper focusses on the concept of the proposed flight-demonstration-experiment and related areas of technological concern. General issues like overall efficiency, pointing accuracy, erosion/degradation, maintenance, and replaceability will be addressed as well. Author

**A87-15897#**
**ADVANCED POWER SUPPLY AND DISTRIBUTION SYSTEMS FOR COLUMBUS**
G. EGGERS (Telefunken AG, Wedel, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 36 p.
(IAF PAPER 86-146)

Power supply and distribution systems designed for Columbus elements, capable of supplying from 8 to 30 kW power to a variety of users in low earth orbits, are described. Special attention is given to the Electrical Power System (EPS), which will deliver electrical power for large-scale space activities. The EPS hardware will be used on the Polar Platform, the Pressurized Module, and the Man-Tended Free Flier. Configuration diagrams and block diagrams are included. I.S.

**A87-15898#**
**A CONCEPT OF THE ENERGY STORABLE ORBITAL POWER STATION (ESOPS)**
R. AKIBA, T. TAKANO, and H. YOKOTA (Tokyo, University, Japan) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. refs
(IAF PAPER 86-149)

To avoid the foreseeable difficulties and risks associated with large scale development of the Space Power Station on GEO at a remote distance, the Energy Storable Orbital Power Station (ESOPS) placed in a near earth orbit is proposed. The most promising orbit for ESOPS is a fixed periapsis pseudo sun synchronous orbit. A thermodynamical power generation is preferable owing to its inherent insensitive nature against radiation suffered on the medium altitude orbit. Thermal energy storage using latent heat of fusion seems the best choice for this system. The power transmission from ESOPS to the ground station presents the most critical problems due to nonstationary characteristics. Author

**A87-15913#**
**ADVANCED PROPULSION STATUS IN WESTERN EUROPE**
M. ANDRENUCCI (Pisa, Universita, Italy), A. ATZEI, C. BARTOLI (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands), G. BAIOCCHI (SNIA-BPD S.p.A., Colleferro, Italy), H. BASSNER (MBB/ERNO, Munich, West Germany) et al. IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 22 p. refs
(IAF PAPER 86-172)

A technology development assessment is made for state-of-the-art spacecraft launch vehicles in Western Europe, where ESA sponsorship is noted to have been extended to all major electric propulsion concepts and the full range of specific impulse, thrust and power levels. Attention is given to such electric propulsion concepts as field emission electric propulsion, RF ion thrusters, MPD, and electrostatic propulsion, as well as to activities under way in the universities of Giessen, Munich, Pisa, Rome, Stuttgart, and Vienna. The Comet Nucleus Sample Return mission's propulsion requirements are discussed. O.C.

**A87-15948#**
**SATELLITE AUTONOMOUS NAVIGATION USING NAVSAT GEO + HEO CONFIGURATION**
C. CARNEBIANCA, G. SOLARI, A. CRAMAROSSA, G. RONDINELLI (Italspazio, Rome, Italy), J. DEZA (Sener Tecnica Industrial y Naval SA, Madrid, Spain) et al. IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. refs
(IAF PAPER 86-227)

The suitability of the Navsat, a future space-based navigation system which has been designed and is being developed by ESA to support Columbus and other LEO applications (such as Hermes, Ariane, rendezvous, and docking) is examined. The paper presents detailed system verification analysis for selected Columbus orbits offered by the Navsat GEO + HEO, demonstrating the suitability of the future navigation system to provide an autonomous navigation capability for space users. The results indicate that the level of performance for positional determination achievable for LEO users exceeds that of other present-day tracking methods and is comparable to that of GPS. I.S.

**A87-15960#**
**INVESTIGATION OF ATTITUDE MOTION OF THE SALYUT-7 ORBITAL STATION FOR LONG TIME INTERVALS**
V. A. SARYCHEV, M. IU. BELIAEV, S. P. KUZMIN, V. V. SAZONOV, and T. N. TIAN (AN SSSR, Institut Prikladnoi Matematiki, Moscow, USSR) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 32 p. refs
(IAF PAPER 86-243)

The uncontrolled rotational motion with respect to the center of mass of Salyut-7 was analyzed for long time intervals. The analysis was based on the statistical processing of onboard measurements of the geomagnetic field strength vector and the vector indicating the direction of the sun. It is shown that, a few days after the beginning of uncontrolled motion, the station was captured into a specific regime of single-axis gravitational orientation, where its longitudinal axis performed stable oscillations with respect to the local vertical, with an amplitude of about 40 deg. The appearance of such a regime was attributed to the interaction between a destabilizing effect of the air drag and a stabilizing effect of energy dissipation by the station equipment. I.S.

**A87-15970#**
**ARP - A MULTIPURPOSE INSTRUMENTATION FOR EXPERIMENTS IN MATERIALS SCIENCES IN SPACE**
R. KUHL (Deutsche Akademie der Wissenschaften, Institut fuer Raumforschung, Berlin, East Germany), H. QUAAS (Berlin, Humboldt-Universitaet, East Germany), and H. SUESSMANN (Halle-Wittenberg, Universitaet, Halle, East Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 12 p. refs
(IAF PAPER 86-260)

Attention is given to automatic recording equipment which has been used sucessfully on-board Salyut-7 and in a terrestrial laboratory for the study of materials sciences processes. The use of this automatic recording equipment in crystal growth processes is discussed. This equipment consists of a data processing and control unit, interchangeable sensors, interchangeable cassettes for data storage, and interchangeable special modules. K.K.

**A87-15971#**
**METALLURGY LABORATORY FOR COLUMBUS**
H. SAINCT, F. JAMIN-CHANGEART, and J.-P. PRAIZEY (Aerospatiale, Paris; CNES, Groupe d'Etudes et de Recherches sur les Materiaux dans l'Espace; CEA, Laboratoire d'Etude de la Solidification, Grenoble, France) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 21 p.
(Contract ESA-6625/85-F-FL-SC)
(IAF PAPER 86-261)

The current status of an ESA preliminary study on the Metallurgy Laboratory for Columbus is reviewed. The review includes a discussion of previous and future experiments, requirements synthesis, and preliminary concepts for services and interfaces. Listed among experiments of potential interest are directional solidification (plane/dendritic), in situ composites (eutectics/immiscibles), artificial composites, and nucleation and glasses. The discussion of services and interfaces covers thermics, power, microgravity, vacuum, safety and reliability, data transmission, and automation. V.L.

**A87-15980#**

**CURRENT AND PERSPECTIVE ITALIAN ACTIVITIES IN MICROGRAVITY RESEARCH AND APPLICATION FROM A SPACE INDUSTRY VIEWPOINT**

F. BORLASTA, F. GIANI, and V. GUARNIERI (AERITALIA S.p.A., Turin, Italy) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 8 p. refs

(IAF PAPER 86-271)

The current status of Aeritalia programs in the design and fabrication of hardware for space microgravity (MG) research and utilization is surveyed, and ongoing promotional efforts are characterized. Topics examined include the successful European participation in MG projects on Spacelab, U.S.-Italian development of a tethered-satellite system (including an elevator component for controlled-G motion along the tether), MG elements for the ESA Eureca and Columbus programs, and consultation/liaison activity leading to Italian participation in MG experiments on D2 (the second German Spacelab mission). T.K.

**A87-16038#**

**DATA RELAY SATELLITE TERMINAL FOR COLUMBUS SERVICE VEHICLE**

A. BAILLY and R. LENORMAND (Alcatel Espace, Toulouse, France) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p.

(IAF PAPER 86-346)

The architecture and implementation problems of the Columbus service vehicle terminal have been investigated, and the results are reported. The mission requirements for each link type are reviewed, and a general description of the service vehicle block diagram and the associated budget links is given. Some details on the S band and Ku band antenna configurations are provided. Two critical items to be studied are identified: (1) the interactions between the antenna and the mechanical structure and (2) the front end layout. C.D.

**A87-16041#**

**ANTENNA SYSTEM ALTERNATIVES FOR DATA RELAY SATELLITES WITH MULTIPLE STEERABLE BEAMS**

H. DODEL, D. FASOLD, E. FRISCH, and M. LIEKE (MBB/ERNO, Ottobrunn, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 7 p. ESA-supported research. refs

(IAF PAPER 86-349)

Antenna system alternatives for data relay satellites are presented. To that end, the European Data Relay Satellite (DRS) as planned by ESA is described in terms of its mission. Constraints on the antenna system are discussed such as imposed by the launcher; the mission as planned foresees an Ariane double launch/bottom position. Various possibilities of combining the S-Band and Ka-Band are outlined, including combined feeds, dichroic reflectors and subreflectors, auxiliary reflectors, beam-waveguide systems, and phased arrays. A considerable number of candidate antenna concepts satisfying the mission requirements are presented (in deployed and stowed configuration on a SPACEBUS-200 type of spacecraft) and their trade-off scores listed. Author

**A87-16055#**

**PROSPECTS FOR THE USE OF THE HIGHER PLANTS IN SPACE FLIGHT EXPERIMENT 'SUBSTRAT'**

T. N. IVANOVA and P. T. KOSTOV (B'lgarska Akademiia na Naukite, Tsentralna Laboratoriia za Kosmicheski Izsledvaniia, Sofia, Bulgaria) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 6 p.

(IAF PAPER 86-374)

A large scientific program has been formulated by Bulgarian scientists for the realization of space vegetable gardens to be used by cosmonauts in space flight as sources of fresh and nutritious food. The stages in which this project is to move toward its goal are summarized, and a laboratory prototype greenhouse is described. The poor results of a first attempt to grow radishes are reviewed, and the 'Substrat' experiment conducted aboard the orbital Salyut-7 station as part of the greenhouse program is described. C.D.

**A87-16056#**

**THE GRAVITATIONAL BIOLOGY LABORATORY (GBL)**

C. CHIPAUX (Matra, S.A., Velizy-Villacoublay, France), P. CLANCY (ESA, Paris, France), W. WODSAK (Dornier GmbH, Friedrichshafen, West Germany), and H. WOLFF (Brunel Institute for Bioengineering, Uxbridge, England) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 6 p.

(IAF PAPER 86-375)

The gravitational biology laboratory (GBL), an integral part of ESA's microgravity research effort, is described. Consideration is given to experimental procedures, engineering of the laboratory, plant cultivation, experiments not requiring illumination, and support laboratory equipment. As part of the Columbus equipment, the GBL will permit experimental undertakings that are forbidden by Eureca and Spacelab mission conditions. When incorporated into the Space Station, the GBL will allow for the growth of rather large plants (up to 1 m). K.K.

**A87-16061#**

**REVIEW OF BASIC MEDICAL RESULTS OF THE SALYUT-7/SOYUZ-T 8-MONTH MANNED FLIGHT**

O. G. GAZENKO, E. B. SHULZHENKO, A. I. GRIGOREV, O. IU. ATKOV, and A. D. EGOROV (Institut Mediko-Biologicheskikh Problem, Moscow, USSR) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 9 p. refs

(IAF PAPER 86-381)

This paper presents the results of medical investigations performed in the Salyut-7 8-month mission in which a professional physician took part. The paper contains anthropometric measurements, the results of investigating the vestibular function, cardiovascular function at rest and in response to multistep tests (with emphasis on echocardiographic measurements), and metabolic parameters and indices of the hormonal status. It also discusses the medical aspects of the extravehicular activity. The medical investigations, (with some new methods applied) provide the continuity of the methodological approaches and of the data accumulated in previous missions. Author

**A87-16062#**

**PLASMA AND URINE CATECHOLAMINE LEVELS IN COSMONAUTS DURING LONG-TERM STAY ON SPACE STATION SALJUT-7**

R. KVETNANSKY, M. VIGAS (Slovenska Akademia Vied, Ustav Experimentalnej Endokrinologie, Bratislava, Czechoslovakia), N. A. DAVYDOVA, V. B. NOSKOV, I. A. POPOVA (Institut Mediko-Biologicheskikh Problem, Moscow, USSR) et al. IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 7 p. refs

(IAF PAPER 86-383)

Results are reported of a study of changes in catecholamine levels in the blood of cosmonauts drawn aboard Space Station Salyut-7 during a long-term mission. The special appliance used to take the samples is described, and levels of epinephrine (EPI) and norepinephrine (NE) found in plasma and urine are reported along with the levels of their metabolites in urine. The levels of EPI and NE are found to have been almost unchanged during space flight. The results suggest a low SAS activity during the late stages of a long-term space flight. C.D.

**A87-16072#**

**ETHICAL PROBLEMS OF INTERACTION BETWEEN GROUND-BASED PERSONNEL AND ORBITAL STATION CREWMEMBERS**

A. I. GRIGOREV, O. P. KOZERENKO, V. I. MIASNIKOV, and A. D. EGOROV (Institut Mediko-Biologicheskikh Problem, Moscow, USSR) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 5 p. refs

(IAF PAPER 86-398)

Manned missions onboard orbital stations Salyut-6 and Salyut-7 have led to the conclusion that a long-term space mission can be

viewed as a complex socioman-machine system whose effectiveness largely depends on the quality of interaction betwewen its subsystems. Psychological and medical examinations before, during and after manned missions have helped in the identification of the major points of interaction of the subsystems which require adequate monitoring and optimization using socio-psychological and organization-technical approaches: (1) arrangement and evaluation of the quality of work, (2) arrangement or proper leisure, and (3) psychological comfort in the interpersonality and intergroup relations during prolonged space missions. This paper also discusses adaptive changes in the mental and physical state due to prolonged exposure to space flight factors such as microgravity and confinement. Author

**A87-16074#**
**THE RECRUITMENT AND ORGANIZATIONAL INTEGRATION OF SPACE PERSONNEL**
K.-M. GOETERS (DFVLR, Institut fuer Flugruedizin, Hamburg, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 5 p.
(IAF PAPER 86-401)
This paper describes the philosophy of selection of astronaut scientists. It deals mainly with psychological selection criteria oriented at the job demands. The results of the European selection campaign for the Spacelab are reported. In addition, some aspects of the organizational integration of astronauts are listed. Author

**A87-16091#**
**THE COMMERCIAL VIABILITY OF ARIANE 5 POUDRE**
G. M. WEBB (Commercial Space Technologies, London, England) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 20 p. refs
(IAF PAPER 86-437)
Consideration is given to European launcher tactics and to the choices which must be made in the face of increasing world competition. The question of whether Europe can continue to possess a commercially viable launcher (A5P), at least up until the advent of fully reusable spaceplanes, or whether the purpose of A5P should be to provide a complementary heavy lift vehicle to Hotol or Sanger II (thus properly satisfying Europe's goals of autonomy) is addressed. It is concluded that: (1) design provision should be made to make A5P multiconfigurable for heavy-lift and contingency use and (2) an unsubsidized commercial role for A5P should be dropped. K.K.

**A87-16111#**
**COLUMBUS FUTURE EVOLUTION POTENTIAL**
G. ALTMANN (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands), G. RAUSCH (Dornier System GmbH, Friedrichshafen, West Germany), and H. SAX (DFVLR, Porz Wahn, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 27 p.
(IAF PAPER 86-462)
The baseline design of Columbus encompasses a permanently attached Space Station pressurized module, a man-tended free-flier (MTFF) pressurized module, a polar-orbit platform to be primarily used for earth observation, and an enhanced version of the Eureca carrier. Attention is given to the ways in which the MTFF could grow to accommodate additional pressurized module requirements. MTFF evolution will require rbotic assistance in research, while the second will pass through two stages, the first of which will require robotic assistance in research, while the second will enhance the manned element and result in greater flexibility. O.C.

**A87-16399**
**SPACE STATION - NASA'S GREATEST CHALLENGE**
T. FURNISS Flight International (ISSN 0015-3710), vol. 130, Aug. 30, 1986, p. 137-140.
An account is given of the progress made by NASA on a Space Station; attention is given to the apportionment of development tasks among NASA facilities and foreign participants in this international project. When completed, the NASA Space Station will encompass four manned modules, of which two will be from the U.S., one from Europe, and the last from Japan. For the first time in any U.S. manned spacecraft, there will be a closed loop environmental control and life support system. O.C.

**A87-16461#**
**REGISTRATION OF THE REMOTE SENSING DATA FROM MULTI-SENSORS**
R. PARVATHI and V. R. RAO (Indian Space Research Organization, Bangalore, India) IN: Asian Conference on Remote Sensing, 6th, Hyderabad, India, November 21-26, 1985, Proceedings . Tokyo, University of Tokyo, 1986, p. 223-229. refs
An attempt has been made to study the imagery obtained with multi-sensors from satellites Landsat, Space Shuttle payloads - MOMS, Metric Camera; SOYUZ (MKF-6), SALYUT-7 (MKF-6M) for the improved information content and feature identification. The positional accuracy of ground control points are studied for different sensors using the affine transformation. The adequacy of the affine transformation with first and and second order polynomials and the number of control points required are analyzed for different satellite imagery. The residual errors and their variation with increasing number of control points are compared with that of Landsat and the results are discussed for registration of multi-satellite data. Author

**A87-16466#**
**ENVIRONMENTAL AND RESOURCE ASSESSMENTS BY MEANS OF METRIC MULTISPECTRAL PHOTOGRAPHY**
K.-H. MAREK, K.-H. JOHN (Akademie der Wissenschaften der DDR, Zentralinstitut fuer Physik der Erde, Potsdam, East Germany), and S. JAEHN IN: Asian Conference on Remote Sensing, 6th, Hyderabad, India, November 21-26, 1985, Proceedings . Tokyo, University of Tokyo, 1986, p. 252-257.

**A87-16496#**
**A COMPARISON OF VISUALLY INTERPRETED SPACE-BORNE DATA FOR GEOMORPHOLOGICAL AND GEOLOGICAL DATA EXTRACTION**
P. K. GUPTA, G. VENKATARAMAN, and S. VISWANATHAN (Indian Institute of Technology, Bombay, India) IN: Asian Conference on Remote Sensing, 6th, Hyderabad, India, November 21-26, 1985, Proceedings . Tokyo, University of Tokyo, 1986, p. 448-452. refs

**A87-16512#**
**COMPARATIVE STUDY OF LANDSAT IMAGERY, MKF-6M AND KATE-140 PHOTOGRAPHS OBTAINED FROM SALYUT-7 SPACE MISSION FOR SOIL RESOURCES MAPPING**
B. R. M. RAO and L. VENKATARATNAM (National Remote Sensing Agency, Hyderabad, India) IN: Asian Conference on Remote Sensing, 6th, Hyderabad, India, November 21-26, 1985, Proceedings . Tokyo, University of Tokyo, 1986, p. 544-551. refs

**A87-16524#**
**INTERPRETATION AND ANALYSIS OF OCEANIC FEATURES OBSERVED ON TERRA IMAGERY OVER LAKSHADWEEP SEA**
H. I. ANDHARIA, S. M. BHANDARI, and N. K. VYAS (Indian Space Research Organization, Space Applications Centre, Ahmedabad, India) IN: Asian Conference on Remote Sensing, 6th, Hyderabad, India, November 21-26, 1985, Proceedings . Tokyo, University of Tokyo, 1986, p. 614-619. refs
Study of the oceanic features observed on the TERRA Imagery collected during Salyut-7 Mission in April 1984 is presented. The selected image is over Lakshadweep Sea and contains a large sun-glint area at the center. At the periphery of the sun-glint region, a number of important oceanic features are clearly visible. The paper describes in detail the observed phenomena and attempts to provide a physical explanation for them in terms of atmospheric and oceanic processes. The paper also describes the physical parameters that can be derived from such features. Author

**A87-18075**

**ARABSAT SOLAR GENERATOR CONCEPT AND IN ORBIT PERFORMANCE**

J. J. JUILLET and L. PELENC (Aerospatiale, Cannes, France) IN: IECEC '86; Proceedings of the Twenty-first Intersociety Energy Conversion Engineering Conference, San Diego, CA, August 25-29, 1986. Volume 3 . Washington, DC, American Chemical Society, 1986, p. 1452-1457.

The capabilities of the Arabsat solar generator are studied. The electrical power subsystem of the satellite which is based on a dual bus direct energy transfer system is examined. The satellite receives its electric energy from two single-axis sun-pointing solar array wings. The components and operation of the solar array wings are described; the solar network is based on silicon solar cells. The performance of the solar array in transfer and geosynchronous orbits and on-station are evaluated by analyzing telemetry data. I.F.

**A87-18201**

**INTERNATIONAL SYMPOSIUM ON SPACE TECHNOLOGY AND SCIENCE, 14TH, TOKYO, JAPAN, MAY 27-JUNE 1, 1984, PROCEEDINGS**

M. NAGATOMO, ED. Symposium sponsored by Ad-Melco Co., Ltd., Akashi Seisakusho, Ltd., Anritsu Electric Co., Ltd., et al. Tokyo, AGNE Publishing, Inc., 1984, 1718 p. For individual items see A87-18202 to A87-18418.

Progress in space science and technology is discussed in reviews and reports, with emphasis on developments in Japan. Topics examined include propulsion, materials and structure, fluid dynamics, thermophysics and thermochemistry, electronic devices, space communication, guidance and control, systems engineering, balloons and recovery technology, earth and planetary observations, astronomy, space medicine and biology, material processing, and space law. T.K.

**A87-18271**

**THE ELECTRON IRRADIATION TEST OF THERMAL CONTROL MATERIAL**

T. MATSUSHITA, M. FUNAKI (National Space Development Agency of Japan, Tokyo), Y. IDO, K. IWAMOTO, Y. MIYAZAKI (Toshiba Corp., Kawasaki, Japan) et al. IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 565-569.

Facilities developed for NASDA to study the degradation and charging effect of thermal control materials are described. The combined irradiation test facility for thermal control materials and the electron irradiation test are presented. The test facility is intended for the following two purposes: investigation of the effect of individual parameters (UV wavelength, electron flux, and temperature) and investigation of combined irradiation of UV and electrons. The test samples of thermal-control material were exposed to 20-keV electron irradiation with flux 2.7 x 10 to the 14th e/sq cm hr. During the test, electrical discharges were frequently observed on the surfaces of test samples such as silvered teflon and OSR. Their solar absorptance and emittance were measured in situ by using a dynamic thermal vacuum technique. Author

**A87-18350**

**EUROPEAN RETRIEVABLE CARRIER - A NEW OPPORTUNITY FOR MICROGRAVITY RESEARCH, SPACE TECHNOLOGY DEVELOPMENT AND SCIENCE APPLICATIONS**

R. MORY (ESA, Space Transportation Systems Directorate, Paris, France) IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 1163-1172.

**A87-18352**

**ELEMENTS OF AN ORBITAL INFRASTRUCTURE AND THEIR UTILIZATION**

H. SAX (DFVLR, Cologne, West Germany) IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 1179-1189.

The utilization aspects of manned and unmanned low earth orbit Space Station elements were studied. Based upon these requirements, four major elements of a future orbital infrastructure were defined under the project title Columbus: pressurized modules, unmanned payload carriers, a resource module, and a service module. The Columbus project aims at a proposal for European participation in the U.S. Space Station program with both manned and unmanned elements to be operated in a Space Station docked mode or as free-flying elements on different orbits, but with the capability of being serviced in orbit. Author

**A87-18363**

**REAL TIME REPORTING SYSTEM ON OCEANIC CONDITIONS BY SPACE STATION**

H. KOSHIISHI, M. NAKA, H. YAMAMOTO, K. MATSUMOTO, K. HOMMA (National Aerospace Laboratory, Chofu, Japan) et al. IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 1263-1270. Research supported by the Fujitsu, Ltd., Hitachi, Ltd., Mitsubishi Electronic Corp., NEC Corp., and Toshiba Corp.

This paper presents some results of conceptual design studies of the Real Time Reporting System on Oceanic Conditions (RTRSOC). By using a Space Station this system can acquire, process, and report world-wide information on oceanic conditions in real time. The sensor system of the RTRSOC is composed mainly of optical and microwave large aperture sensors which are realized only in the Space Station. A high speed onboard data processing system is indispensable for real time image processing and analysis. The RTRSOC mission has great significance for industrial activities, and will also be able to meet many of the future requirements for remote sensing. Author

**A87-18462**

**THE COMMUNICATION AND CONTROL SYSTEM OF JAPANESE EXPERIMENT MODULE FOR SPACE STATION**

I. IIZUKA (National Space Development Agency of Japan, Tokyo), M. KUDOH, I. EGUCHI, Y. MINAMI, M. TAKAHASHI (NEC Corp., Yokohama, Japan) et al. IN: Space exploitation and utilization; Proceedings of the Symposium, Honolulu, HI, December 15-19, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 173-182. (AAS PAPER 85-615)

Japan's contribution to the NASA Space Station, the Japanese Experiment Module (JEM), is reported to be in the planning stage. The JEM is to be operated by a crew of one or two and so must be a highly automated or autonomous system. It is now planned to install a high-speed computer and an optical local area network, with which all subsystems and missions will be controlled. JEM control will be accomplished on three levels: the system administration level, the subsystem control level, and the individual control level. The command deployment structure (using macro commands) and the constant checkout structure are designed to minimize crew workloads. D.H.

**A87-18478**

**THE INTERESTS OF JAPANESE INDUSTRY FOR COMMERCIALIZATION OF SPACE**

S. OOBAYASHI (Ishikawajima-Harima Heavy Industries, Ltd., Tokyo, Japan) IN: Space exploitation and utilization; Proceedings of the Symposium, Honolulu, HI, December 15-19, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 429-439. (AAS PAPER 85-650)

Enterprises in Japan, relating to electronics or biomaterials, will begin to conduct space experiments in material processing in the coming years. However, Japan, not having its own spaceflight capability until the Space Station becomes available, will want to

participate in other countries' space flights. As the trend for the utilization of space becomes more apparent, the Japanese government will take measures such as establishing a promotion organization and an incentive system. Japanese enterprises plan to conduct, in the 1990s, fundamental experiments on the JEM (Japan Experiment Module) of the Space Station, as well as experiments for practical use and production on the free flyer. D.H.

**A87-18483**

**PRELIMINARY CONCEPT OF RMS FOR JAPANESE EXPERIMENT MODULE OF THE SPACE STATION**

K. SHIRAKI (National Space Development Agency of Japan, Tokyo), H. MARUMO, Y. SUGASAWA, and S. NISHIDA (Toshiba Corp., Kawasaki, Japan) IN: Space exploitation and utilization; Proceedings of the Symposium, Honolulu, HI, December 15-19, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 517-523.
(AAS PAPER 85-662)

A preliminary JEMRMS (Japanese Experiment Module/Remote Manipulator System) concept for inclusion aboard the Space Station is explained. The main RMS tasks are to assist in attaching and detaching the experimental logistics module from the JEM and to handle the Orbital Replacement Unit (ORU), to minimize crew time and hazardous tasks involved in extravehicular activity. The RMS consists of a small, fine-control arm and a main arm with a standard end-effector (SEE). D.H.

**A87-19734**

**THE WATCH GAMMA-BURST DETECTOR FOR EURECA-I**

NIELS LUND (Dansk Rumforskningsinstitut, Lyngby, Denmark) IN: X-ray instrumentation in astronomy; Proceedings of the Meeting, Cannes, France, December 2-4, 1985 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 95-100. refs

The WATCH gamma-burst detector is to be flown on the ESA microgravity satellite Eureca-I. The unique feature of the WATCH detector is its capability for real-time localizations of the sources of strong gamma-ray bursts. The expected source localization accuracy is about 10 arcminutes. WATCH will not only study gamma bursts but also detect hard-X-ray transients and monitor the X-ray sky in the energy band from 5 to 120 keV. Author

**A87-19837**

**ADVANCED SOLAR GENERATOR TECHNOLOGY FOR THE EURECA LOW EARTH ORBIT**

L. GERLACH and B. GOERGENS (Telefunken AG, Wedel, West Germany) IN: Photovoltaic Specialists Conference, 18th, Las Vegas, NV, October 21-25, 1985, Conference Record . New York, Institute of Electrical and Electronics Engineers, Inc., 1985, p. 78-83.

The paper presents the design and related activities of the Electrical Part of the EURECA Solar Array based on the shadow protection requirement and the extreme environment due to the atomic oxygen effects in the EURECA low earth orbits combined with a high (20,000) number of thermal cycles. Trade-off studies for the solar cell selection have been performed to determine the optimum cell type in respect to power-to-mass ratio and cost effectiveness. The paper summarizes the verification program and identifies the solar cell technology to be applied for low earth orbit missions with extended mission life (10 years) equivalent to 60,000 thermal cycles. Author

**A87-20215#**

**THE CREW WORK-STATION TEST-BED FOR COLUMBUS**

J. HOWIESON, W. OCKELS, G. WEIJERS (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands), and A. SEIBL (MBB-ERNO Raumfahrttechnik GmbH, Bremen, West Germany) ESA Bulletin (ISSN 0376-4265), no. 47, Aug. 1986, p. 52-59.

Manned spaceflight involves both man and machine. The interface between them plays an essential role in determining how the capabilities and effectiveness of each can be enhanced by working together. Because of the importance of the Man/Machine Interface (MMI) and its susceptibility to rapid advances, ESA is establishing a reference facility for the assessment and validation of new MMI technology for manned space systems. It will initially be used as a crew-work-station test-bed for the Columbus Project. Author

**A87-20218#**

**THE AGENCY'S FRACTURE-CONTROL TECHNOLOGY PROGRAMME**

G. REIBALDI (ESA, Spacecraft Technology Dept., Noordwijk, Netherlands) ESA Bulletin (ISSN 0376-4265), no. 47, Aug. 1986, p. 69-72.

Fracture-control methodology, management, and technology are discussed as well as the objectives of ESA's Fracture-Control Technology Program. This program will attempt to derive maximum benefit from the common technology needs of future programs and from closer cooperation with industries working outside the aerospace domain, i.e., nuclear and offshore. It is noted that the Space Station/Columbus, Ariane-5, and Hermes programs all require the application of fracture-control procedures for crew safety. K.K.

**A87-20677**

**FLYING INTO THE FUTURE**

CLIVE SIMPSON Spaceflight (ISSN 0038-6340), vol. 28, April 1986, p. 147-151.

Hotol, an aerospace plane being considered by the UK space industry, is characterized and illustrated with drawings. Hotol is intended to provide manned or unmanned launches to LEO for about 7 tonnes of payload, satellite recovery services, and docking with the NASA Space Station or ESA Columbus. A completely reusable configuration based on an advanced hydrogen/oxygen hybrid engine is foreseen, and it is predicted that Hotol could compete for 75 percent of the commercial launch market after the year 2000. Also included is a brief comparison of Hotol and Hermes. T.K.

**A87-20680**

**INTERNATIONAL COOPERATION - NEW INITIATIVES IN SPACE**

RICHARD R. COLINO (INTELSAT, Washington, DC) Spaceflight (ISSN 0038-6340), vol. 28, July-Aug. 1986, p. 282-288.

The need for international cooperation in space missions is examined. Consideration is given to the individual space programs of the Soviet Union, China, Japan, and Western Europe, and the Spacelab and proposed Space Station missions. The international cooperation involved in the formation of Intelsat, and the proposed development of an aerospace vehicle are discussed. I.F.

**A87-21050#**

**ONBOARD ORBIT DETERMINATION USING DATA RELAY SATELLITE**

V. N. NGUYEN (ONERA, Chatillon-sous-Bagneux, France) (ESA, International Symposium on Spacecraft Flight Dynamics, 2nd, Darmstadt, West Germany, Oct. 20-23, 1986) ONERA, TP, no. 1986-148, 1986, 7 p. CNES-supported research. refs
(ONERA, TP NO. 1986-148)

A technique for using range and/or Doppler data transmitted by way of one or two data relay satellites (DRS) to find a spacecraft position in LEO is described. Emphasis is placed on automated identification of position and velocity of a spacecraft in an eccentric transfer orbit on the final circular orbit. LEO-DRS or LEO-DRS-ground signal measurements with known accuracy are made at regular intervals and processed through a Kalman filter. A model is defined for accounting for the orbit parameters, bias, and Markovian noises. Applications of the method are illustrated with simulated positioning computations for the SPOT and EURECA spacecraft. M.S.K.

**A87-21806**
**FRENCH NATIONAL ACTIVITY ON SPACE NUCLEAR POWER SYSTEMS**
CLAUDE POHER (CNES, Paris, France) IN: Space nuclear power systems 1985; Proceedings of the Second Symposium, Albuquerque, NM, Jan. 14-16, 1985. Volume 3 (87-21801 08-20). Malabar, FL, Orbit Book Co., Inc., 1987, p. 43-45. CNES-sponsored research.

French studies related to the development of space nuclear electricity generators, and various applications for the generators are described. The French generator, ERATO, is a He Brayton cycle turboalternator system composed of pairs of contrarotating machines with a power specification of 50 kw(e) for each machine; the generator is designed for use on an Ariane 5 launcher. The development of a cold source for the generator which is small, light, and has a high temperature, and the need for maximum energy conversion efficiency are discussed. I.F.

**A87-21975**
**PERSPECTIVE ON NON-U.S. PRESENTATIONS AT THE 37TH CONGRESS OF THE INTERNATIONAL ASTRONAUTICAL FEDERATION - OCTOBER 4-11, 1986, INNSBRUCK, AUSTRIA**
J. HARTFORD, ED. (AIAA, New York) New York, American Institute of Aeronautics and Astronautics, 1987, 41 p. No individual items are abstracted in this volume.

Highlights of the plenary events and technical sessions of the 37th Congress of the International Astronautical Federation are presented. Particular attention is given to the state and direction of foreign space technology, and to foreign reaction to U.S. papers. Subject areas include astrodynamics, communications satellites, earth observations, economics, education, global change, history, life sciences, materials and structures, microgravity processes, propulsion, and the search for extraterrestrial intelligence. Consideration is also given to space exploration, space law, space power, space stations, space systems, and space transportation. K.K.

**A87-22050**
**ARE THE SOVIETS AHEAD IN SPACE?**
THOMAS Y. CANBY National Geographic (ISSN 0027-9358), vol. 170, Oct. 1986, p. 420-459.

The developmental history of the Soviet space program is traced and future plans are discussed. Emphasis is placed on developments regarding Space Stations, Shuttle-type vehicles, space industries, and missions to the moon and Mars. Consideration is also given to the military implications of the Soviet space program. The salvaging of the crippled Salyut 7 Space Station is described in detail. It is argued that the Soviet space budget approximates that of the U.S. (the equivalent of about 22 billion dollars for 1985) but probably doubles the U.S. commitment in terms of gross national product. K.K.

**A87-24123#**
**THE INTERNATIONAL SPACE STATION TAKES SHAPE [DIE INTERNATIONALE RAUMSTATION NIMMT GESTALT AN]**
SABINE HOLL Luft- und Raumfahrt (ISSN 0173-6264), vol. 7, 3rd Quarter, 1986, p. 76-79. In German.

European technological contributions to the proposed Space Station are reviewed. The Europeans are involved in the design, development, and utilization of such components as a pressurized module, polar platforms, and data processing units. The orbital and terrestrial infrastructure of the Columbus including data processing and telecommunication systems concerned with the coordination of operations on the Station are examined; various applications for the Station are proposed. Consideration is given to the financing of the program, the allocation of costs, the composition of the crew and workload, the allocation of time for use of the Space Station facilities, and technology transfer. I.F.

**A87-24238**
**FLUX OF NUCLEI WITH ENERGIES OF SEVERAL HUNDRED MEV/NUCLEON IN THE SALYUT-6 ORBIT [O POTOKE IADER S ENERGIEI NESKOL'KO SOT MEV/NUKLON NA ORBITE STANTSII 'SALIUT-6']**
K. BLAZH, V. V. BOBROVSKAIA, G. P. GERTSEN, N. L. GRIGOROV, M. ZHOBANU et al. Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 24, Sept.-Oct. 1986, p. 770-777. In Russian. refs

The latitudinal distribution of the flux of nuclei with energies of several hundred MeV/nucleon was measured in the Salyut-6 orbit (a height of 350 km and an inclination of 51.6 deg). The experiment used the Astro-2 instrument, in which nitrocellulose detectors were cyclically shifted with respect to one another. The experimental results do not agree with theoretical calculations of the penetration of galactic cosmic rays to the Salyut-6 orbit. Possible reasons for this discrepancy are discussed. B.J.

**A87-24577**
**AN INTRODUCTION TO THE SYMPOSIUM ON HEAT AND MASS TRANSFER ON EARTH AND IN MICROGRAVITY**
PHILIP GOLDSMITH (ESA, Paris, France) (British Association for Crystal Growth, International Organization of Crystal Growth, ESA, et al., International Conference on Crystal Growth, 8th, York, England, July 13-18, 1986) Journal of Crystal Growth (ISSN 0022-0248), vol. 79, no. 1-3 (pt. 1), Dec. 1986, p. 37-42.

Past and ongoing ESA activities in organizing and sponsoring space crystal-growth experiments are surveyed, and plans for future experiments are outlined. The implications of microgravity containerless-processing methods and the virtual elimination of buoyancy-driven convection for crystal growth are reviewed; experiments performed on Skylab, Apollo-Soyuz, the first Spacelab project, and 1985 Shuttle flights (including the German D-1 mission) are described; and the experiments being developed and evaluated for D-2, Eureca, and Columbus are considered, emphasizing the greatly increased capacity (tons of payload times days in orbit) of Columbus. Diagrams, graphs, and tables listing experiment and facility parameters are provided. T.K.

**A87-24709#**
**COLUMBUS COMMUNICATIONS SUBSYSTEM DESIGN**
A. FLORIO and L. BARDELLI (Selenia Spazio S.p.A., Rome, Italy) IN: Digital networks and their evolution - Space and terrestrial systems; Proceedings of the Thirty-third International Congress on Electronics and Twenty-sixth International Meeting on Space, Rome, Italy, Mar. 18-20, 1986 . Rome, Rassegna Internazionale dell'Elettronico, dell'Energia, e dello Spazio, 1986, p. 295-311.

In this paper a summary description is presented of the Columbus European Space Station in general and the related Communications System, mainly concerning the Pressurized Module for in-orbit experiments and the Resource Module providing the necessary power and equipments for RF links towards the TDRS, EUDRS, USSS, orbiters and ground stations. The corresponding scenarios and configurations are schematized and the block diagrams are presented/described of the Communications Subsystem both for Pressurized Module and Resource Module. Examples of link budgets for RF links in KU band and KA band are provided. Author

**A87-24874**
**'SALYUT-6' STUDIES THE BIOSPHERE - AN INVESTIGATION OF THE NATURAL ENVIRONMENT FROM SPACE BASED ON THE SOVIET-HUNGARIAN PROGRAM 'BIOSPHERE-M' [SALIUT-6' IZUCHAET BIOSFERU-ISSLEDOVANIE PRIRODNOI SREDY IZ KOSMOSA PO SOVETSKO-VENGERSKOI PROGRAMME 'BIOSFERA-M']**
IU. P. KIENKO, ED. and P. SHTEFANOVICH, ED. Moscow, Izdatel'stvo Mashinostroenie, 1986, 148 p. In Russian.

The book presents the results of space and ground experiments carried out within the context of the Soviet-Hungarian program 'Biosphere-M'. These experiments were conducted as part of a study of the earth's surface using space remote sensing data. Images of mountainous regions, cyclones, cloud covers, and fronts

which were obtained from the 'Salyut-6' platform are included. Consideration is given to the scientific and methodological aspects of space remote sensing of the earth's surface, flight preparation, and space information and its uses. K.K.

**A87-25448**

**EURECA - A RETRIEVABLE FREE-FLYER FOR COMMERCIAL APPLICATIONS**

D. J. SHAPLAND and R. MORY (ESA, Directorate of Space Station and Platforms, Paris, France) International Space Business Review, vol. 1, July-Aug. 1986, p. 62-66.

The European Retrievable Carrier (Eureca), which bridges the gap between the present time and the arrival of the Space Station, is discussed. The cost and commercial applications of the Eureca and its operational concept are reviewed, and its design is described. The first Eureca flight, scheduled to take place in early 1988 with retrieval six months later, is briefly described, and Eureca's microgravity applications and mission potential are summarized. Some cost considerations are addressed, and the relation of Eureca to the Space Station is discussed. C.D.

**A87-25454#**

**PRESENT AND FUTURE SCENARIOS FOR CANADIAN MATERIALS PROCESSING IN SPACE**

RICHARD BOUDREAULT, RICK ESCHER, and CHRIS CATERALL (Canadian Astronautics, Ltd., Space Systems Div., Ottawa, Canada) IN: Space Station: Gateway to space manufacturing; Proceedings of the Conference, Orlando, FL, Nov. 7, 8, 1985 . Arlington, VA, Pasha Publications, 1985, 25 p. refs

Technological and economic aspects of space materials processing are reviewed, with an emphasis on Canadian scientific and commercial programs. The useful properties of the space environment are described; the effects of microgravity disturbances on materials processing are considered; the payload, power availability, altitude, and duration of current and planned microgravity support systems such as Shuttle GAS and Hitchhiker, Space Station, Eureca, Leasecraft, and LDEF are listed in a table and discussed; Canadian activities are outlined; and cost analyses of the available options are presented graphically. It is concluded that specialized unmanned free flyers are the most viable commercial space-processing option (combining low cost and a high-quality microgravity environment), but that manned missions are essential for performing basic research and R&D work. T.K.

**A87-25533**

**THE USSR AND SPACE POWER PLANTS**

ALAIN DUPAS (CNES, Paris, France) Space Policy (ISSN 0265-9646), vol. 2, Nov. 1986, p. 361, 362. refs

Soviet policy on space power plants is examined. Research from Soviet space experts relating to the feasibility and development of space power plants is analyzed. Consideration is given to the time scale and costs of development, and the use of laser technology in satellite solar power stations. The research reveals that Soviet space experts are in favor of developing space power plants. I.F.

**A87-25559**

**MAINTAINING A SPACE STATION**

DIETRICH HAESELER Spaceflight (ISSN 0038-6340), vol. 28, Dec. 1986, p. 426-429. refs

The equipment, resupply flights and crew supplies which have been expended to maintain the Soviet space stations are summarized. It is estimated that the crew required 13.4 kg/day of consumable items, while experimental work necessitated 2.4 kg/day. Mass breakdowns are provided for the individual spacecraft and payloads involved in the Salyut program, including all mass launched into orbit and returned to earth. Mass, component and supply projections are also made for the basic configuration of the Mir space station, which may reach a total 140 tons. It is believed that a greater degree of robotics and automation will be introduced into the Mir space station to lower the human/instrument supply mass ratio. M.S.K.

**A87-25751**

**SPACE TECH '86; PROCEEDINGS OF THE INTERNATIONAL CONFERENCE, GENEVA, SWITZERLAND, MAY 14-16, 1986**

London, Online International, Ltd., 1986, 261 p. For individual items see A87-25752 to A87-25769.

Papers are presented on the development of the Space Station, the Japanese laboratory proposal, and the Columbus program. Topics discussed include free flying platforms, the role of robotics in space, switches, lasers, and electronically-hopped beam antennas in space, new communications satellite configurations, geostationary platforms, the mobile communications satellite, and paging by satellite. Consideration is given to space transportation, in particular the Long March launcher, Ariane 5/Hermes, and Hotol. I.F.

**A87-25753**

**JAPANESE LABORATORY PROPOSAL**

TADAHICO INADA (National Space Development Agency of Japan, Paris, France) IN: Space Tech '86; Proceedings of the International Conference, Geneva, Switzerland, May 14-16, 1986 . London, Online International, Ltd., 1986, p. 21-31.

Japanese participation in the Space Station Phase B study is concentrated on the experimental module, which is attached to the core module from one side, and other facilities, which are attached to the other side. The basic principles for participation and detailed configuration of the module are described. Author

**A87-25755**

**ELEMENTS OF FUTURE AUTONOMY - THE SERVICE VEHICLE REFERENCE CONCEPT AND DERIVATIVES**

PATRICK EYMAR (Aerospatiale, Les Mureaux, France) IN: Space Tech '86; Proceedings of the International Conference, Geneva, Switzerland, May 14-16, 1986 . London, Online International, Ltd., 1986, p. 45-59.

Studied during Columbus phase B1, the Service Vehicle had reached a high level of definition. No longer a part of the IOC this spacecraft remains a cornerstone of future European autonomy. Its design will evolve from the present STS optimized concept toward an Ariane 5-Hermes one. Other derivatives may also be considered. Author

**A87-25764**

**ARIANE 5/HERMES - THE EUROPEAN CONTENDER FOR SPACE TRANSPORTATION**

BARNARD T. DELOFFRE (Aerospatiale, Paris, France) IN: Space Tech '86; Proceedings of the International Conference, Geneva, Switzerland, May 14-16, 1986 . London, Online International, Ltd., 1986, p. 169-175.

The development of a system composed of a Space Station (Columbus), a manned vehicle (Hermes), and a launch vehicle (Ariane) to provide Europe with manned free access to low orbits is discussed. The main characteristics of Ariane 5/Hermes are described in terms of system requirements. Particular attention is given to safety, lift-off mass limitations, and development costs. Diagrams of the proposed Ariane 5/Hermes are presented. I.F.

**A87-25769**

**COLUMBUS - THE HABITABLE MODULE**

C. BUONGIORNO (Ministry of Science and Technology, Space Office, Italy) and E. VALLERANI (Aeritalia S.p.A., Settore Spazio, Naples, Italy) IN: Space Tech '86; Proceedings of the International Conference, Geneva, Switzerland, May 14-16, 1986 . London, Online International, Ltd., 1986, p. 229-249.

The design and functions of the pressurized module being developed in the Columbus program for the Space Station are analyzed. The development of a pressurized module that is either attached or an integral element of the Space Station is examined; the advantages of the two designs are described. Consideration is given to the thermal control, atmosphere pressure and composition control, ventilation, and water dispersal systems of the module. The attachment of a resource module to the integral pressurized module is discussed. The use of the pressurized module as a free flyer or as a habitation module is studied.

Diagrams of the internal and external structure of the pressurized module, the resource module, and the habitation module are presented. I.F.

**A87-25832**

**THE EURECA PLATFORM - SYSTEM DEFINITION, UTILIZATION, AND FOLLOW-ON DEVELOPMENT**

JUERGEN K. VON DER LIPPE (MBB-ERNO Raumfahrtechnik GmbH, Bremen, West Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 10, Sept.-Oct. 1986, p. 328-337.

The baseline characteristics and the microgravity and nonmicrogravity missions of the Eureca platform system are discussed. The overall concept, structure, power system, thermal control system, data handling system, telemetry/telecommand system, attitude and orbit control system, and microgravity measurement system are described. Multiuser facilities, 'add-on' experiments, space science experiments, technology experiments pertaining to the microgravity missions are addressed. The astronomy mission, solar physics mission, and earth observations under nonmicrogravity conditions are considered. C.D.

**A87-27452**

**SOVIET REMOTE SENSING**

K. IA. KONDRATEV and IU. P. KIENKO (Academy of Sciences, Remote Sensing Institute, USSR) Space (ISSN 0267-954X), vol. 2, Dec. 1986-Feb. 1987, p. 11-15.

Initial Soviet progress in satellite earth imaging systems was in applications for meteorology, climatology, and oceanography. Subsequent systems were dedicated to hydrologic and geologic mapping missions, chiefly through thematic mapper instrumentation. A new emphasis is being put on linking global earth resources monitoring systems and moving remote sensing systems from experimental to operational status. Sample images of the U.S.S.R. are provided, noting recent attempts to integrate the remote sensing functions of Kosmos and Meteor satellites, the Mir and Salyut space stations, airborne, fixed and mobile ground and sea stations. A chief goal of current remote sensing is exploration for mineral deposits. M.S.K.

**A87-27456**

**THE NEW OLYMPIAN**

OWEN BOWLES (British Aerospace, PLC, Space and Communications Div., Stevenage, England) Space (ISSN 0267-954X), vol. 2, Dec. 1986-Feb. 1987, p. 31, 32, 35, 36.

The Olympus F1 platform, due for first launch in 1988 after an extensive testing program, is designed to accommodate multiple payloads with a high degree of commonality. Intended for launch on the Ariane 3 or the STS, the F1 can comprise a 3,300 kg launch mass and furnish a 600 kg payload with a 10 yr lifetime with 7 kW power from solar panels. Eclipse power is 3.8 kW from either Ni-Cd or Ni-H batteries. The thermal dissipation system can be configured to handle solid-state amplifiers or TWTAs consuming 3.7-5.5 kW of power. Details of the ground links and data transfer capabilities, power handling equipment, propulsion and thermal control systems, and possible future enhancements of the Olympus platform are described. M.S.K.

**A87-27462**

**TOROIDAL COIL CONFIGURATIONS FOR A LARGE-ACCEPTANCE SPACE SPECTROMETER**

G. BASINI, M. RICCI, P. SPILLANTINI (Istituto Nazionale di Fisica Nucleare, Frascati, Italy), S. BARTALUCCI (Istituto Nazionale di Fisica Nucleare, Frascati, Italy; European Organization for Nuclear Research, Geneva, Switzerland), F. BONGIORNO (Istituto Nazionale di Fisica Nucleare, Frascati; Roma, Universita, Rome, Italy) et al. Nuovo Cimento C, Serie 1 (ISSN 0390-5551), vol. 9, Sept.-Oct. 1986, p. 953-960.

The paper reports the study of a toroidal coil designed for a spectrometer to be located in a manned space station in earth orbit. Acceptances of the order of 100 sq m sr can be obtained using toroidal coil configurations characterized by a weight and complexity compatible with techniques presently available for transporting the spectrometer from earth to space. It is concluded that the toroidal magnet is the best compromise between large acceptance and strong bending power; it represents an excellent solution for experiments in which the counting rate is the main limitation. K.K.

**A87-27781#**

**SOLAR PANELS FOR SPACE APPLICATIONS [ZONNEPANELEN VOOR TOEPASSINGEN IN DE RUIMTEVAART]**

A. M. V. VIELEERS (Fokker, Amsterdam, Netherlands) Ruimtevaart, vol. 35, Oct. 1986, p. 9-20. In Dutch.

The current development status of solar panels for spacecraft is surveyed, with an emphasis on projects underway at Fokker. The materials and operating parameters of modern Si solar cells are listed in a table and discussed; design aspects of body-mounted and deployable solar panels are considered; the power requirements (ranging from 0.5 to 250 kW) of different classes of spacecraft are indicated; advanced rigid arrays (being developed for Inmarsat, Telecom, SAX, SOHO, Olympus, DRS, and UK DBS) and retractable and retrievable arrays (being developed for Eureca and Leasecraft) are described and illustrated with drawings; and the Strongback array for Columbus is briefly characterized. T.K.

**A87-28129**

**THE EUROPEAN COLUMBUS PROGRAMME**

ANTS KUTZER (MBB-ERNO Raumfahrttechnik GmbH, Bremen, West Germany) IEEE Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 2, Jan. 1987, p. 2-12.

The current status of the Columbus program is discussed. The configurations, requirements, and operations of the pressurized laboratory module and polar platform are examined. The module is to be utilized for materials science, fluid physics, and life sciences, and the platform for observations of the earth, meteorology, communications, and space science payloads. The design and capabilities of the man-tended free flyer, which consists of a resource module and a two-segment pressurized module, are described. Diagrams of the pressurized module, polar platform, and man-tended free flyer are provided. I.F.

**A87-28131**

**THE JAPANESE EXPERIMENT MODULE**

HIDEO HASEGAWA (National Space Development Agency of Japan, Houston, TX) IEEE Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 2, Jan. 1987, p. 17-23.

The basic configuration and primary functions of the Japanese Experiment Module (JEM) are described. The JEM consists of a pressurized module, an exposed facility, a scientific/equipment airlock, a local remote manipulator, and an experimental logistic module; the functions of each component are discussed. The JEM layout, control and management system, and operational concept are examined. The JEM is to be utilized for general scientific and technology development research, life science and materials processing experiments, and to house the control panels for the Space Station Mobile Remote Manipulator System and attached payloads. Diagrams of the JEM and its components are presented. I.F.

**A87-28544**

**MODAL ANALYSIS TECHNIQUE USED IN GERMANY FOR AEROSPACE STRUCTURES**

N. NIEDBAL (DFVLR, Institut fuer Aeroelastik, Goettingen, West Germany) IN: International Modal Analysis Conference, 4th, Los Angeles, CA, Feb. 3-6, 1986, Proceedings. Volume 1 . Schenectady, NY, Union College, 1986, p. 378-385. refs

Modal-survey testing is an increasingly common part of the qualification procedure for aerospace structures, since it offers an experimental verification of normal mode parameters determined by dynamic finite-element analysis. Moreover, it permits identification of structural damping, knowledge of which is essential for reliable flight-load calculations for space structures. A state of the art of modern modal-survey testing is given here, covering the phase-resonance method and various phase-separation methods. The use of modal-survey results in the dynamic

qualification of aerospace structures is discussed, emphasising the correlation of analytical and experimental modal data. This aspect has attracted growing interest in recent years, due to the obvious need for convenient tools that allow finite-element models to be updated with measured modal data. Author

**A87-28954**
**INTERNATIONAL USE OF NATIONAL SPACE STATION FACILITIES**
S. R. DAUNCEY (General Technology Systems, Ltd., Brentford, England) British Interplanetary Society, Journal (Space Stations) (ISSN 0007-084X), vol. 40, Jan. 1987, p. 27-31.

The purpose of this paper is to raise consciousness as to the need to plan the use of Space Station as an ongoing organism. This is done by trying to give a picture of what the Space Station may become, mentioning some possibly comparable organizations and suggesting some analogies (leaving it to the reader to think in more detail about the lessons to be learned) and drawing some very tentative conclusions. Author

**A87-28955**
**PAYLOAD OPERATIONS ON THE COLUMBUS POLAR PLATFORM**
D. C. FERNS, D. W. LYTTON, and M. DILLON (Logica Space and Defence Systems, Ltd., Cobham, England) British Interplanetary Society, Journal (Space Stations) (ISSN 0007-084X), vol. 40, Jan. 1987, p. 33-38. refs

Design requirements for the payloads and instruments of the Columbus Polar Platform are proposed. Consideration is given to the payload development life cycle, the need for an interface between the payload and payload carrier, payload test phases, and payload simulators. The payload communications data link, and the ground segment design are examined. I.F.

**A87-28956**
**TOWARDS A USER-FRIENDLY SPACE STATION**
D. E. MULLINGER British Interplanetary Society, Journal (Space Stations) (ISSN 0007-084X), vol. 40, Jan. 1987, p. 39-42.

The views of Spacelab investigators who participated in the SL-1 and D-1 missions as regards the user-friendliness of the Spacelab system are analyzed, and recommendations for maximizing the user-friendliness of the Space Station are presented. The technical capabilities of the Spacelab system, mission preparation, and mission operations are examined. The need for a user-interface organization and for easier and simplier access to systems and crew is discussed. Requirements to make the preparation phase, integration and testing, and payload operations more user-friendly are proposed. I.F.

**A87-29061**
**AUTONOMOUS NAVIGATION AND CONTROL OF THE SALYUT-7 ORBITAL STATION [AVTONOMNAIA NAVIGATSIIA I UPRAVLENIE ORBITAL'NOI STANTSIEI 'SALIUT-7']**
E. V. GAUSHUS, IU. N. ZYBIN, and V. P. LEGOSTAEV Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 24, Nov.-Dec. 1986, p. 844-864. In Russian. refs

The structure and design principles of the complex of Salyut-7 navigation and control systems are examined in detail. Particular consideration is given to the various operational modes of the Del'ta navigation and control system. B.J.

**A87-29353**
**INDUSTRIAL APPLICATIONS OF MICROGRAVITY [LES APPLICATIONS INDUSTRIELLES DE LA MICROGRAVITE]**
J.-L. CHAREIRE (Aerospatiale, Division Systemes Balistiques et Spatiaux, Les Mureaux, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 119, 1986, p. 41-53. In French.

The state-of-the-art in microgravity materials processing and possible French activities in the field are discussed. Access to space, for the near-term, depends on participation in Shuttle flights or the Soviet Salyut and Mir programs. Later, France will be a partner in the Ariane V, Hermes and Columbus programs. Current NASA pricing policies for Shuttle missions are examined, noting potential savings with the EURECA free-flyer. The techniques necessary for studying the formation of organic and inorganic materials in microgravity are examined, and results obtained in protein crystallization and thermal migration of Co during the Skylab and Apollo-Soyuz missions are reviewed. The economic implications of commercial-scale production of latex spheres, ultrapure GaAs semiconductors and electrophoretically-separated materials is considered. M.S.K.

**A87-29358**
**THE EURECA ENERGY SUPPLY SYSTEM. I - AN EXAMPLE OF ENERGY SUPPLY FOR FUTURE AUTONOMOUS PLATFORMS [DAS ENERGIEVERSORGUNGSSYSTEM FUER EURECA. I - BEISPIEL FUER DIE ENERGIEVERSORGUNG KUENFTIGER AUTONOMER PLATTFORMEN]**
HEINZ KOEBEL (Telefunken AG, Wedel, West Germany) Astronautik (ISSN 0004-6221), vol. 23, Oct.-Dec. 1986, p. 121-123. In German.

The energy demands, electric current production, energy storage, and energy distribution of the EURECA (European Retrievable Carrier) are discussed. Data for the EURECA are given along with a diagram of the energy supply system. The influence of the EURECA solar generator and energy distribution system on future space platforms is discussed. C.D.

**A87-29368**
**THE DYNAMICAL QUALIFICATION OF PRESENT AND FUTURE SPACECRAFT STRUCTURES [DIE DYNAMISCHE QUALIFIKATION HEUTIGER UND ZUKUENFTIGER RAUMFAHRTSTRUKTUREN]**
AXEL BERTRAM, HORST HUENERS, and WERNER SACHS (DFVLR, Institut fuer Aeroelastic, Goettingen, West Germany) DFVLR-Nachrichten (ISSN 0011-4901), Nov. 1986, p. 56-61. In German.

The dynamical design-verification procedures employed by the DFVLR Institut fuer Aeroelastik for spacecraft development are discussed, with a focus on the performance and analysis of modal survey tests. The mobile static-vibration-test facility and the modal-analysis programs for the Olympus platform, the Ariane-4 payload shroud, and the ESA Simple and Complex Models (hypothetical spacecraft designed to test the accuracy of modal-synthesis techniques) are described and illustrated with drawings, diagrams, and photographs. In the latter tests, modal synthesis is found to be a very useful design tool, but one requiring considerable experience on the part of the designer. The need for improved model-updating strategies and for new test concepts to simulate flight loads and analyze subassemblies is indicated. T.K.

**A87-29402**
**OVERVIEW/COMMERCIAL SPACE MARKETS FROM A EUROPEAN POINT OF VIEW**
F. DALLEST (Arianespace, Evry; CNES, Paris, France) IN: Space commerce '86; Proceedings of the International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, June 16-20, 1986 . Geneva, Interavia Publishing Group, 1986, p. 11-14.

Present and future markets for European space hardware, services and launch capabilities are described. The success of Intelsat has led to the strong growth in DBS systems and lower-cost individual antennas. The business of providing corporate satellite links and satellite-based mobile telecommunications services is expected to grow dramatically. Existing and future generations of the EOSAT (Landsat) and SPOT services will eventually return the private and public investments in remote sensing technologies. Both European and U.S. commercial subsidiaries are now being set up to market meteorological satellite data and provide navigation and radiopositioning systems. Access to space will continue to be with the Ariane and STS, with a birth of competition from Japanese, Soviet and Chinese launch services. Finally, construction of the Space Station and launches of free-flyers will increase the amount of privately-funded materials-processing research carried out in space. M.S.K.

**A87-29409**
**MANUFACTURING IN SPACE**
ALAIN ESTERLE (CNES, Paris, France) IN: Space commerce '86; Proceedings of the International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, June 16-20, 1986 . Geneva, Interavia Publishing Group, 1986, p. 81-94.

Materials processing experiments on Spacelab 1 demonstrated that such activities may eventually be scaled up to commercial size, particularly in the fields of bioseparation, cell culture, cell fusion, solidification and crystallization. Further fundamental studies are necessary to assess achievable economic goals and which processes and specific products are worth targeting for development. NASA has encouraged and subsidized basic research and is being joined by Japanese researchers. European researchers are beginning serious work and funding of orbital systems such as EURECA and the COLUMBUS module. Attention is given to current and near term French applications-oriented programs for identifying developing products and production processes in potentially commercial-scale materials processing areas. The allocation of public funds and solicitation of private and international investments are discussed. M.S.K.

**A87-29415**
**EUROPEAN SHUTTLE/SPACELAB USER EXPERIMENT FACILITIES**
MANFRED E. KUEBLER (Dornier System GmbH, Friedrichshafen, West Germany) IN: Space commerce '86; Proceedings of the International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, June 16-20, 1986 . Geneva, Interavia Publishing Group, 1986, p. 183-198.

The features of several microgravity user facilities either produced or being developed by Dornier with ESA funding for basic research and prototype commercial operations are described. The devices were either flown on the Spacelab D1 mission or are intended for the D2 mission or the EURECA free-flyer. The functional parameters, capabilities and uses of the Mirror Heating Facility (first generation), the Monoellipsoidal Mirror Furnace (second generation) and the Automatic Mirror Furnace are summarized. The Bridgman Gradient Heating Furnace, Advanced Gradient Heating Facility and the Containerless Electromagnetic Processing Facility are also described, along with various apparatus for the Biorack and their arrangement in the payload racks. Future development efforts are targeted at, e.g., better temperature control, the provision of optional environmental conditions, and advanced robotics for experiment handling. M.S.K.

**A87-29418**
**ACTIVITIES TOWARDS INDUSTRIALIZATION IN SPACE IN GERMANY**
PETER KLEBER (DFVLR, Cologne, West Germany) IN: Space commerce '86; Proceedings of the International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, June 16-20, 1986 . Geneva, Interavia Publishing Group, 1986, p. 217-224.

West German space industrialization activities are described. Work is being performed by the private user industry, service industries, centers of excellence, national/international authorities and organizations, and the aerospace industry. The Federal Ministry of Research and Technology originated microgravity research. BMFT and DFVLR jointly performed the TEXUS sounding rocket experiments and developed the SPAS free-flyer. DFVLR in 1983 initiated a campaign to interest nonaerospace companies in space research. MBB-ERNO is now building the EURECA free flyer. Private industry is focusing attention on microgravity materials processing, while centers of excellence at universities conduct interdisciplinary research in solidification front dynamics, numerical analysis, biotechnology, material science, and fluid mechanics. The government supplies most initial funds, an necessary arrangement at the current level of space industrialization. M.S.K.

**A87-29425**
**FACILITIES FOR THE SPACE INDUSTRIALIZATION PRESSURIZED MANNED MODULES FROM SPACELAB TO SPACE STATIONS**
ERNESTO VALLERANI (Aeritalia S.p.A., Turin, Italy) IN: Space commerce '86; Proceedings of the International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, June 16-20, 1986 . Geneva, Interavia Publishing Group, 1986, p. 295-312.

European development of space modules started with the manufacture of Spacelab modules. The Spacelab experience is being exploited to design the Columbus module of the International Space Station (ISS), and may lead to separate logistics, experimentation and habitation derivatives. Consideration is being given by the prime ESA pressurized module contractor, Aeritalia, to modules both attached to the ISS and configured as free flyers. A cylindrical segmented reference design has been identified. Each module has end airlocks and four viewing ports that can be replaced by airlocks. Modular interior furnishings and experiments will allow complete changeouts over the lifetime of the modules. Rack-mounted hardware and proposed uses of the equipment are outlined. Variations on the basic design to provide the Spacehab, a mid-deck habitable extension of Orbiter, and to use a free flyer as the cornerstone for building a European Space Station coorbiting with the ISS are discussed. M.S.K.

**A87-29428**
**COLUMBUS**
FREDRIK ENGSTROEM (ESA, Paris, France) IN: Space commerce '86; Proceedings of the International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, June 16-20, 1986 . Geneva, Interavia Publishing Group, 1986, p. 325-338.

The agreement by ESA to furnish the Columbus module for the International Space Station (ISS) is the culmination of a long intent to form a partnership with the U.S. in space activities. The module provides a starting point for eventual European autonomy in space, and a base for experimentation which is expected to lead to new products manufactured on earth and in space. The European contribution is to include a permanently attached pressurized module, a man-tended, pressurized free flyer, a polar platform, and a coorbiting platform based on EURECA technology. All components, like other Station elements, are expected to be openly shared among participating states. The motivations for the different elements are discussed, along with projected management, cost, commercial proprietary, and operational factors which must be considered during Station design. M.S.K.

**A87-29432**
**OPERATION REMOTE SENSING ACTIVITIES - ESA-EARTHNET REVIEW AND FUTURE PLANS**
LUIGI FUSCO (ESA, Earthnet Programme Office, Frascati, Italy) IN: Space commerce '86; Proceedings of the International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, June 16-20, 1986 . Geneva, Interavia Publishing Group, 1986, p. 372-380.

The facilities, data products and dissemination system, and planned and projected future activities of the ESA Earthnet Program Office (EPO) for distributing remote sensing data are described. The network features three receiving and processing stations at two centers for SAR data. Data is preprocessed at user request and provided in the form of raw and corrected magnetic tape and/or B/W films and prints, enlargements, or color composites. The data can be accessed at the EPO office, a network of National Points of Contact in ESA member states or associate countries, and distribution centers outside the member states. Archives of images can be interrogated through the Space Informatics Network Experiment, which provides digitized searches and data transmission. Data from the ERS-1, Tiros-N, Columbus, EURECA and polar platform sensors are to be distributed with the Apollo digital data dissemination network, which will work through the medium of the Eutelsat series of communication satellites. M.S.K.

**A87-29494#**
**SPACE STATIONS - A PEACEFUL USE FOR HUMANITY?**
NICOLAS MATEESCO MATTE (McGill University, Montreal, Canada) IN: Annals of air and space law. Volume 10 . Montreal, McGill University, 1985, p. 417-451. refs

The history of NASA and Soviet Space Station activities and constraints placed on Space Station activities by international agreements are explored. The Soviets launched the first Salyut Space Station in 1971, followed by launch of Skylab in 1973. The Soviets have since orbited several Salyut modules while NASA was developing the Shuttle, which was at first to be the supply vessel for a Space Station but has become the primary launch vehicle. The initiation of a U.S. Space Station program has become an international effort, primarily exploiting European capabilities developed in the Spacelab program. The Space Station will be governed by all current conventions regulating the use of outer space. Issues of registration and liability for Space Station components are discussed. M.S.K.

**A87-30421#**
**PLANT PHYSIOLOGY RESEARCH IN SPACE**
WOLFRAM LORK and VOLKER STROBEL Dornier Post (English Edition) (ISSN 0012-5563), no. 3, 1986, p. 54, 55.

A technology demonstration project - Biosample - is described that is to be capable of performing biological experiments automatically, as may be required for unmanned missions such as EURECA (European Retrievable Carrier) or the man-tended free flyer (MTFF). Biosample provides different sophisticated manipulations of samples by dedicated mechanisms, but can also be used in a manned laboratory to save crew time for other tasks. The relationship between gravitropism and phototropism is considered in particular. For operation in space the system would have to fulfill the following conditions: different temperature compartments (0 - 30 C); humidity control; control of gas composition (especially CO2); removal of toxic or impairing agents; total darkness; irradiation with monochromatic light (optionally polarized) from different directions; observation on IR illumination; centrifuges to allow accelerations between 0 and 3 g for application of gravistimuli and/or 1-g reference experiments (lateral and longitudinal); seeding, germination, and cultivation of the plantlets; and fixation of plant tissues to study morphological changes. A proposed ground-based experiment using gravitational 'pulses' from a centrifuge is described. D.H.

**A87-31220#**
**DEPLOYMENT ANALYSIS OF THE OLYMPUS ASTROMAST AND COMPARISON WITH TEST MEASUREMENTS**
M. EIDEN, O. BRUNNER, and C. STAVRINIDIS (ESA, European Space Research and Technology Center, Noordwijk, Netherlands) (Structures, Structural Dynamics, and Materials Conference, 26th, Orlando, FL, Apr. 15-17, 1985, Technical Papers. Part 1, p. 325-332) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, Jan.-Feb. 1987, p. 63-68. Previously cited in issue 13, p. 1894, Accession no. A85-30264.

**N87-10143** European Space Agency. European Space Operations Center, Darmstadt (West Germany).
**OLYMPUS: APOGEE ENGINE FIRING**
R. MUGELLESI and W. FLURY *In* CNES Proceedings of an International Conference on Space Dynamics for Geostationary Satellites p 475-491 1986
Avail: CEPADUES-Editions, 111 rue Nicolas-Vauquelin, 31100 Toulouse, France

The apogee engine firing of OLYMPUS is analyzed taking into account the positioning at the on-station longitude in the geostationary orbit. One and two-burn strategies are considered for two thrust steering policies: inertially fixed thrust direction, and constant rotation of the thrust vector around a fixed axis. It is shown that the mass loss with two burns stays below 0.06% (reference = impulsive transfer). Constant rotation of the thrust vector leads to a slightly better performance than an inertially fixed thrust direction. ESA

**N87-10880#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany).
**EUROPEAN UTILIZATION ASPECTS OF LOW EARTH ORBIT SPACE STATION ELEMENTS, PHASE 3, VOLUME 2 Final Report**
Paris ESA Oct. 1985 755 p Prepared in cooperation with Aeritalia S.p.A., Torino, Rome, British Aerospace Aircraft Group, Bristol, England, Dornier-Werke GmbH, Friedrichshafen, West Germany, Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost, Netherlands, Instituto Nac
(Contract ESA-5234/82-F-FC(SC))
(ESA-CR(P)-2219; ETN-86-98099) Avail: NTIS HC A99/MF E03

European utilization aspects of space station pressurized module, and co-orbiting, polar and free-flying platforms are summarized. Materials science; life sciences; Earth observation; technology and communication; user interfaces; payload handling; and user data bases are covered. ESA

**N87-10893#** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Mechanical Systems Div.
**ESA FRACTURE CONTROL POLICY AND FRACTURE MECHANICS SPECTRA FOR STS PAYLOADS**
G. G. REIBALDI, A. A. TENHAVE, A. U. DEKONING, and J. P. VANHERWAARDEN (Royal Netherlands Aircraft Factories Fokker, Amsterdam) *In* ESA Proceedings of an International Conference on Spacecraft Structures p 51-55 Apr. 1986
Avail: NTIS HC A19/MF A01

In order to standardize the fatigue load spectra used in the design of European payloads to be flown on the Space Shuttle, the European Space Agency evaluated acceleration flight data from several Space Shuttle missions. Data were derived from a variety of payload mass, size, location, and complexity to be as general as possible. Fracture mechanics loading spectra verification and correct prediction is considered very important for complex payloads and space station elements. Requirements for materials properties, stress intensity solutions, crack growth prediction algorithms, loading spectra, nondestructive inspection, fracture of composites, creep, and probabalistic fracture mechanics are discussed. ESA

**N87-10919#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. of Aeroelasticity.
**EXPERIENCE ON THE OLYMPUS MODAL SURVEY TEST**
M. KNORR and A. BERTRAM *In* ESA Proceedings of an International Conference on Spacecraft Structures p 247-252 Apr. 1986
Avail: NTIS HC A19/MF A01

A modal survey test (MST) on two configurations of the large structure test model of the Olympus communications satellite is described: A configuration with the main tanks 2/3 full, the second with empty tanks. The complete MSTs were finished within 4 weeks, including installation and strip down of the test equipment. The spacecraft was mounted on a 40 t seismic block. The satellite is characterized by large dimensions, mass, and complexity. This made it necessary to install a number of exciters and accelerometers at inaccessible structural points several months prior to testing. The test was performed using a computer-supported classical phase resonance method. The day-by-day data transfer via data tape enabled the customer to correlate measured and calculated eigenmodes immediately and to perform orthogonality checks at the end of a working day. ESA

**N87-10924#** Saab-Scania, Linkoping (Sweden).
**TELE-X ANTENNA MODULE STRUCTURE QUALIFICATION PROGRAM**
T. ANDERSSON *In* ESA Proceedings of an International Conference on Spacecraft Structures p 283-288 Apr. 1986
Avail: NTIS HC A19/MF A01

The qualification program for the TELE-X Spacecraft Antenna Module Structure is presented. The CFRP structure is adapted to a Cassegrain system with extreme thermal stability requirements.

Requirements constraining the design and the qualification program to verify the structure ability to meet these requirements are described. Analysis models used and experience from test predictions and model correlations are presented. ESA

**N87-10925#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Space Group.
**INFLUENCE OF FIBER ORIENTATION AND BOUNDARY CONDITIONS ON THE DYNAMIC BEHAVIOR OF A CYLINDRICALLY TELESCOPING SOLAR ARRAY (INTELSAT 6)**
E. D. SACH, H. J. HUETTMANN, and E. FRITSCHE *In* ESA Proceedings of an International Conference on Spacecraft Structures p 289-292 Apr. 1986
Avail: NTIS HC A19/MF A01
To meet the strong frequency requirements in stowed configuration of the INTELSAT 6 solar array (2 central telescoping cylinders in sandwich design, the face sheets of which are made of aramid fiber fabric and carbon fiber fabric) analyses were performed to show the influence of fiber orientations, number of layers and stiffener rings and boundary conditions on the dynamic behavior. The investigations show that each reinforcement measure is effective only in a very limited range. To fulfill the frequency requirement with a minimum structural mass, a combination of several reinforcements is necessary. ESA

**N87-10927#** Societe Nationale Industrielle Aerospatiale, Les Mureaux (France).
**DEVELOPMENT OF A LIGHTENED STRUCTURE FOR THE GSR3 SOLAR GENERATOR [DEVELOPPEMENT D'UNE STRUCTURE ALLEGEE DE GENERATEUR SOLAIRE GSR3]**
A. PLAGNE and J. P. REAU *In* ESA Proceedings of an International Conference on Spacecraft Structures p 299-304 Apr. 1986 In FRENCH
Avail: NTIS HC A19/MF A01
Weight reduction techniques employed in the GSR3 solar generator (35W/kg end of life) are described. The surface mass of the structure is 900 to 1050 g/sqm depending on the degree of optimization of stacking points. The structure is highly versatile, and can be used fully or partly deployed. Carbon fiber composite was chosen to meet weight and sizing constraints. ESA

**N87-10956#** Marconi Space Systems Ltd., Portsmouth (England).
**MODERN CONTROL OF LARGE FLEXIBLE SPACECRAFT, ESA ASTP STUDY Final Report**
Paris ESA May 1985 272 p
(Contract ESA-5664/83-NL-BI; ESTEC-5352/83-NL-HP(SC))
(BL-6206-ISSUE-2; ESA-CR(P)-2197; ETN-86-98083) Avail: NTIS HC A12/MF A01
Stability control of large flexible spacecraft using bang-bang nonlinear control based on Sturm's theorem was investigated. A canonical model for preliminary tuning of the Sturm control law was derived. The damping matrix for the control law was studied. Use with one and two flexure modes per array axis; state estimation; stationkeeping maneuver responses; effect of parameter mismatches; and effect of mode spillover were assessed. Comparisons with other techniques show that the Sturm controller is superior, particularly with respect to ability to reject orbital correction disturbance. ESA

**N87-11066#** Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Space Div.
**OFFSET UNFURLABLE ANTENNA. PHASE 2A: EXECUTIVE SUMMARY**
Paris ESA Nov. 1985 34 p
(Contract ESTEC-5206/82-NL-PB(SC))
(MBB-R-0200/3069-R; ESA-CR(P)-2199; ETN-86-98085) Avail: NTIS HC A03/MF A01
A 4.5 m radial rib reflector was designed for the 4 GHz Intelsat mission. The reflector was redesigned for the M-Sat 2-beam coverage requirements, resulting in a 5 m dia, 850 MHz offset reflector. It features a radial carbon fiber rib concept where foldable main ribs and intermediate ribs tension a gold plated molybdenum mesh to the required surface contour. The accuracy is varied by applying different numbers of ribs (e.g., 16 for 850 MHz or 30 for 12 GHz) and mesh fastening points. The electrical performance criteria used to establish the acceptable mechanical tolerances is that the level of the gore lobes generated by the ribs remains at least 30 dB below the main beam peak under all orbital conditions. ESA

**N87-11352#** British Aerospace Dynamics Group, Bristol (England). Space and Communications Div.
**HPSA: HIGH POWER SOLAR ARRAY STUDY Final Report**
C. P. LEE Paris ESA Jul. 1985 156 p
(Contract ESA-6064/84-NL-PB)
(BAE-TP-8071; HPSA/RPT/8071; ESA-CR(P)-2201; ETN-86-98086) Avail: NTIS HC A08/MF A01
A 30 kW solar array design for ESA's Columbus program was established. Realistic array requirements were identified using the ESA recommended designed reference mission. System and subsystem level studies lead to preferred design solutions for silicon and gallium arsenide cell technologies. A development philosophy and test plan to pursue the identification of critical aspects was derived and a preliminary cost appraisal was made. It is concluded that a planar double roll out array employing silicon cells represents the most attractive solution, with a gallium arsenide roll out as a logical derivative. ESA

**N87-11810** Joint Publications Research Service, Arlington, Va.
**COMMENTARY, DIAGRAM OF MIR STATION**
M. CHERNYSHOV *In its* USSR Report: Space (JPRS-USP-86-005) p 1 - 3 12 Sep. 1986 Repr. from Moscow News (Moscow, USSR), no. 20, 25 May - 1 Jun. 1986 p 10
Avail: NTIS HC A11/MF A01
The flight from the Mir Space Station to the Salyut-7 Space Station (3,100 kilometers) by cosmonauts Leonid Kizim and Vladimir Solovyoy and its applications to future manned space flight are discussed. B.G.

**N87-11814** Joint Publications Research Service, Arlington, Va.
**INTERVIEW ON MEDICAL PROGRAM OF 237-DAY FLIGHT**
O. Y. ATKOV, O. G. GAZENKO, and Y. I. CHAZOV *In its* USSR Report: Space (JPRS-USP-86-005) p 142 152 12 Sep. 1986 Transl. into ENGLISH from Zemlya i Veselennaya (Moscow, USSR), no. 5, Sep. - Oct. 1985 p 49-56
Avail: NTIS HC A11/MF A01
The crew of Mayaki (beacons), L. D. Kizim, V. A. Solovyev, and O. Yu. Atkov spent 237 days working on board the Salyut-7/Soyuz orbital scientific research complex conducting an intensive program of medical and biological research. The execution of the program, some of the results of the research, and experiments conducted were discussed. B.G.

**N87-11833#** Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
**DOCKING MECHANISMS TECHNOLOGY STUDY Final Report**
Paris ESA Nov. 1984 70 p
(Contract ESA-5195/82-NL-BI)
(ESA-CR(P)-2273; ETN-86-98138) Avail: NTIS HC A04/MF A01
A zero impact docking concept, where the attitude orbit control system (AOCS) of the chaser spacecraft performs a close-up maneuver within the range of the latching subassembly, is proposed. The AOCS-controlled closure is a feasible solution of the last meter problem taking typical European rendezvous and docking (RVD) mission scenarios into account. The European standard docking interface is characterized by the prism seats on the chaser and the handles on the target. The servicing concept fits well within the modular docking mechanism subsystem approach with minimum interface problems. The latching concept giving high modularity and adaptability can be tailored to the specific mission needs without changing the baseline. A minimum of RVD equipment has to be furnished additionally to existing chaser capabilities to perform the RVD last-meter-approach. ESA

**N87-12109#** Joint Publications Research Service, Arlington, Va.
**PRELIMINARY RESULTS OF MEDICAL INVESTIGATIONS DURING 5-MONTH SPACEFLIGHT ABOARD SALYUT-7-SOYUZ-T ORBITAL COMPLEX**
Y. I. VOROBYEV, O. G. GAZENKO, Y. B. SHULZHENKO, A. I. GRIGORYEV, A. S. BARER, A. D. YEGOROV, and I. A. SKIBA *In its* USSR Report: Space Biology and Aerospace Medicine, Vol. 20, No. 2, Mar. - Apr. 1986 (JPRS-USB-86-004) p 33 - 42 23 Jul. 1986 Transl. into ENGLISH from Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina (Moscow, USSR), Vol. 20, No. 2, Mar. - Apr. 1986, p 27-34
Avail: NTIS HC A07/MF A01

The medical examinations carried out in the 150-day flight were a continuation of previous studies in terms of the approaches and methods used. The novel approach was a biochemical study of body fluids collected during flight. An important place was occupied by medical monitoring and support performed during extravehicular activity (EVA). The medical results of the 150-day flight were consistent with the data obtained during previous spaceflights of similar duration. The health condition and work capacity of the crewmembers throughout the flight (including two EVA events) were good. The changes seen during and after flight were adaptive and disappeared after a relatively short readaptation period.
Author

**N87-12135#** Joint Publications Research Service, Arlington, Va.
**BIOLOGICAL VALUE OF PROTEINS IN FOOD ALLOWANCE OF SALYUT ORBITAL STATION CREWS**
V. P. BYCHKOV, T. F. VLASOVA, V. N. GRYAZNOVA, Y. A. SEDOVA, A. K. SIVUK, V. A. TRETYAKOVA, and A. S. USHAKOV *In its* USSR Report: Space Biology and Aerospace Medicine (JPRS-USB-86-006) p 64-69 8 Oct. 1986 Transl. into ENGLISH from Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsin (Moscow, USSR), v. 20, no. 4, Jul. - Aug. 1986 p 44-48
Avail: NTIS HC A08/MF A01

The biological value of the protein component of three modifications of the Salyut space diet was measured in laboratory studies and in simulated space flights. Three experimental runs of up to 68 days in duration were carried out on 20 volunteers. During the study the following parameters of protein metabolism were measured: total protein and protein fractions in serum; urea, uric acid and creatinine in blood; total nitrogen, urea, ammonia, uric acid and creatinine in urine. The results obtained showed that the diet modifications provided an adequate nutritional status and a normal level of the above parameters of protein metabolism.
Author

**N87-12596#** Instituto de Pesquisas Espaciais, Sao Jose dos Campos (Brazil).
**COMPARISON OF METHODS FOR THE CALCULATION OF THERMAL CONTACT RESISTANCE OF THE FIRST BRAZILIAN SATELLITE M.S. Thesis, 6 Dec. 1985 [COMPARACAO DE METODOS PARA O CALCULO DA RESISTENCIA TERMICA DE CONTATOS DO PRIMEIRO SATELITE BRASILEIRO]**
M. B. H. MANTELLI Apr. 1986 105 p In PORTUGUESE; ENGLISH summary
(INPE-3864-TDL/217) Avail: NTIS HC A06/MF A01

A comparative study of the methods developed for the calculation of thermal contact resistance between two surfaces submitted to a perpendicular heat flux is presented. Several factors affecting this resistance are analyzed and a brief historical review of the works in this field is made, spotting the methods of interest for spacial applications. These are compared to experimental data so as to establish the most proper method for the couplings of the first Brazilian satellite.
Author

**N87-13460#** Joint Publications Research Service, Arlington, Va.
**USSR REPORT: SPACE**
12 Nov. 1986 196 p Transl. into ENGLISH from various Russian articles
(JPRS-USP-86-006) Avail: NTIS HC A09/MF A01

Translations of various Russian periodicals are presented. The subject area headings are: Manned mission highlights, Space sciences, Interplanetary sciences, Life sciences, Space engineering, Space applications, Space policy and administration, and Launch table. Some representative titles are: Cosmonauts deploy girder from Salyut-7; Origin of series of s-bursts in solar radio emission; Commentary of Phobos project; The effect of space flight factors on the muscle system; Number of impulses in coplanar minimum fuel flight between close Keplerian orbits; Upgrading of COSPAS-SARSAT system; Space official on USSR commercial launch services with proton rocket; and List of recent Soviet space launches.

**N87-13589#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany).
**ACTIVITIES REPORT IN MATERIALS AND CONSTRUCTION Annual Report, 1985 [FORSCHUNGSBEREICH WERKSTOFFE UND BAUWEISEN]**
1985 114 p In GERMAN
(ISSN-0174-3910; ETN-86-98280) Avail: NTIS HC A06/MF A01

Research in materials and construction methods is presented. Structural mechanics, aeroelasticity, and space simulation are covered.
ESA

**N87-13626#** MATRA Espace, Toulouse (France).
**STUDY OF FREQUENCY SELECTIVE SYSTEMS. PART 1: PRELIMINARY INVESTMENTS ON SHAPES AND LATTICES; SOFTWARE DEVELOPMENTS. PART 2: INTERFACING OF POLITECNICO FSS PROGRAMS WITH MATRA REFLECTOR ANTENNA SOFTWARE. PART 3: APPLICATION TO MACS PHASE 2 TX ANTENNA (MATRA)**
P. G. MANTICA, R. TASCONE, R. ORTA, and R. ZICH Paris, France ESA Dec. 1985 230 p Prepared in cooperation with Politechnico di Torino, Italy, and Satcom International, Toulouse, France
(Contract ESA-5279/82-F-RD(SC))
(ANT/NTEA/04.85; DE/GE/006.85; ESA-CR(P)-2271; ETN-86-98140) Avail: NTIS HC A11/MF A01

The impact of frequency selective surfaces (FSS) on an offset Cassegrain satellite antenna comprising one solid main reflector, two dichroic subreflectors, and the feed clusters was assessed. Patch shapes and lattices were studied in order to develop FSS software. The FSS programs were interfaced with reflector antenna software. The complete package was applied to the MACS phase 2 TX antenna. Results show that the software can analyze any common FSS configuration with all necessary details: single or multigrid periodic structures (conductive patches) inserted in a sandwich of dielectric layers. The link with reflector antenna software allows an accurate prediction of overall antenna performance. Analysis reveals cross-polarization limitations in offset configuration, and phase shifts in dual-grid configuration with a wide range of incidence angles. This leads to a depointing of the beam radiated by the antenna. To compensate, two solutions appear feasible: either repoint the whole antenna, or vary the spacing between the two grids with respect to the incidence angles.
ESA

**N87-13864#** Societe Nationale Industrielle Aerospatiale, Cannes (France). Div. Systemes Balistiques et Spatiaux.
**HIGH POWER RIGID SOLAR ARRAY Final Report**
L. PELENC Paris, France ESA 19 Sep. 1985 121 p
(Contract ESTEC-6061/84-NL-PB(SC))
(SNIAS-917A-CA/CG; ESA-CR(P)-2202; ETN-86-98087) Avail: NTIS HC A06/MF A01

The feasibility and complexity of a 30 kW solar array scaling 15 to 60 kW for the Columbus space station, with silicon cells and with gallium arsenide cells were studied. The specifications were modified, thereby changing the concept choice for the study. The multideployment/retraction (300 for the mission) and the 20% power required in partial deployment (under 3 kN reboost engines) favor rigid arrays for both silicon and gallium arsenide cells, with a very simple and reliable pantograph deployment/retraction system.
ESA

**N87-14419#** SATCOM International, Paris (France).
**COMPARISON OF FUTURE COMMUNICATIONS SPACE SEGMENT CONCEPTS Final Report**
P. MOLETTE, P. SAINT-AUBERT, C. COUGNET, B. CLAUDINON, R. W. YOUNG, J. MURDOCH, and D. HELAS Toulouse, France Matra Espace Sep. 1982 414 p
(Contract ESA-4818/81-NL-MD)
(DM51-C/PM/FL/0100.82; ESA-CR(P)-2011-VOL-1; ETN-87-98643) Avail: NTIS HC A18/MF A01

A large platform, which can be assembled either in geostationary orbit (resulting in several launches, rendezvous and docking), or in low Earth orbit by using the STS; and a cluster of satellites, designed to meet the requirements of a communication mission were compared. They are characterized by the required number of modules to be launched, the type of launcher, and subsystems or equipments to be developed. The concepts are evaluated following technical criteria such as adaptability to other missions, flexibility, and growth potential. A cost/benefit evaluation of each solution is presented. The concepts are compared as to the technical/economical attractiveness of each solution. The critical elements of the concepts are pointed out and lead to the analysis of a possible demonstration mission. ESA

**N87-15252#** Indian Space Research Organization, Trivandrum.
**POSSIBLE AREAS OF COLLABORATION BETWEEN DFVLR AND ISRO IN THE FIELDS OF STRUCTURES AND MATERIALS**
V. GOWARIKER *In* DFVLR Colloquium about Joint Projects within the DFVLR/ISRO Cooperation p 143-148 Jul. 1986
Avail: NTIS HC A08/MF A01; DFVLR, Cologne, West Germany DM 46

Research possibilities in large space structures and microgravity experiments on composites and polymers are outlined. ESA

**N87-15990#** Joint Publications Research Service, Arlington, Va.
**OVERVIEW OF PLANNED TESTS OF SPACE MATERIALS**
*In its* Japan report: Science and Technology (JPRS-JST-86-018) p 41-43 2 Jul. 1986 Transl. into ENGLISH from Toshi Keizai (Tokyo, Japan), Jan. 1986 p 52-53
Avail: NTIS HC A05/MF A01

The National Space Development Agency (Japan) started space materials tests by using the two-stage rocket TT III 500 A. As the next step, full scale space tests that make use of the Spacelab are scheduled to take place in early 1988. The next rounds of tests that follow will take place on the space station. These projects are briefly outlined. B.G.

**N87-16322*#** Messerschmitt-Boelkow-Blohm/Entwicklungspring Nord, Bremen (West Germany).
**DESIGN AND DEVELOPMENT OF A TELESCOPIC AXIAL BOOM**
ROLAND FELKAI *In* NASA. Lewis Research Center The 20th Aerospace Mechanics Symposium p 1-12 May 1986
Avail: NTIS HC A14/MF A01 CSCL 22B

A special telescopic boom has been design-optimized, developed and qualified to carry an S-band antenna for the German Telecommunication Satellite is discussed. The design driver requirements, the alternatives investigated, the final technical solution, the tests performed, and special problem areas encountered during its development are discussed. Author

**N87-16924#** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Structures and Configurations Section.
**ANTENNA MECHANICAL TECHNOLOGIES WITHIN ESA**
G. G. REIBALDI *In its* Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 5-13 Aug. 1986
Avail: NTIS HC A12/MF A01

Antenna concepts under development within ESA, including solid, depolyable, unfurlables, and inflatable reflectors are surveyed. Technologies needed to support such antenna concepts in the area of materials, analysis, testing, manufacturing, mechanisms, and attitude and orbit control systems/structures coupling are presented. The need to have technology commonality between different requirements is emphasized. ESA

**N87-16928#** Toshiba Research and Development Center, Kawasaki (Japan). Space Program Div.
**STUDY ON SOLID SURFACE, DEPLOYABLE ANTENNA REFLECTOR**
Y. TSUTSUMI, A. KASAHARA, Y. HISADA (National Space Development Agency, Ibaraki, Japan), and Y. ITOH *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 41-45 Aug. 1986
Avail: NTIS HC A12/MF A01

A study was carried out on the precision-contour solid surface, deployable reflector in the 20 to 30 GHz, center-fed Cassegrain antenna to be mounted on data relay and tracking satellites. Reflector sizes are 1.8 m stowed diameter and 5 m deployed diameter. As a solid surface deployable reflector to satisfy the above requirements, two kinds of deployment concepts were developed. Based on the kinematic analysis results, preliminary design was carried out and a partial model was built to confirm the deployment kinematics. Deployment test results, using a partial model, show that two deployment concepts can be applied to the solid surface deployable reflector satisfying the requirements of a large ratio of deployed/stowed dimensions. ESA

**N87-16938#** European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
**GIOTTO SPACECRAFT HIGH GAIN ANTENNA MECHANICAL DESIGN AND DEVELOPMENT**
R. HALM, F. FELICI, H. J. SCHOEDEL (Dornier-Werke G.m.b.H., Friedrichshafen, West Germany), and H. RAUPP *In its* Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas (date) p 123-126 Aug. 1986
Avail: NTIS HC A12/MF A01

The development approach of the Giotto spacecraft high gain antenna structure is presented. The antenna structure consists of a dynamically and statically balanced offset parabolic reflector and a tripod support structure for the S/X-band feed. The reflector dish is a sandwich construction having CFRP face sheets employing ultra high module fibers bonded to an aluminum honeycomb core. The tripod is designed to provide the required eigenfrequencies by stiff profiles made of CFRP. ESA

**N87-16939#** Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
**DEVELOPMENT STATUS OF THE ERS-1 SAR ANTENNA**
R. WAGNER, H. J. LUHMANN, R. SIPPEL, and M. WESTPHAL *In* ESA Proceedings of the Second ESA Workshop on Mechanical Technology for Antennas p 131-137 Aug. 1986
Avail: NTIS HC A12/MF A01

A 10 m x 1 m planar array antenna for the ERS-1 satellite is described. It features metallized CFRP waveguides as radiating elements and feeding network components, CFRP sandwich reinforcements of the mechanical panels, a deployable truss structure, and mechanism for launch fixation, release, and deployment. Mechanical design of the antenna structure towards satisfactory dynamic properties in launch configuration within the narrow constraints of mass, volume, and mechanical loads; structural analysis of the stowed and deployment antenna, to determine dynamic properties, internal loads, and deformations; and design of the hold down and release mechanism arrangement of six hinged clamps for launch fixation, to be released via a system of springs and cables by a pyrotechnic device, are reviewed. ESA

**N87-17056#** Aeritalia S.p.A., Torino (Italy). Space System Div.
**THE WELDING OF ALUMINUM ALLOYS: A NEW TECHNOLOGY IN SPACE APPLICATION**
P. MARCHESE and G. BANING *In* AGARD Advanced Joining of Aerospace Metallic Materials 11 p Jul. 1986
Avail: NTIS HC A12/MF A01

The optimization of the structural weight of the Spacelab structure, the first European manned laboratory designed according to shuttle requirements, led to the choice of 2219-T851 aluminum alloy, T.I.G. welded with the process completely developed and qualified from Aeritalia as briefly described is this paper. To demonstrate the high quality and reliability of the welded primary structure, new inspection techniques, many different tests on the welded joint, and expensive fracture mechanics analysis were applied. The main assumptions and results are presented. The main efforts were concentrated on the reduction of number and size of welding defects, improving, on the one side, the welding technique and on the otherside, inspecting single defects after fracture mechanics analysis based on sophisticated measurement of their dimensions, on the schematization of embedded flaw in tension and bending, and on carefull measurement of material properties. Possible improvements of T.I.G. application for future space programs (space station) or its substitution with plasma welding processes are also mentioned. Author

**N87-17152*#** Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
**FEATURES AND TECHNOLOGIES OF ERS-1 (ESA) AND X-SAR ANTENNAS**
R. SCHUESSLER and R. WAGNER *In* JPL The Second Spaceborne Imaging Radar Symposium p 125-129 1 Dec. 1986
Avail: NTIS HC A10/MF A01 CSCL 09C

Features and technologies of planar waveguide array antennas developed for spaceborne microwave sensors are described. Such antennas are made from carbon fiber reinforced plastic (CFRP) employing special manufacturing and metallization techniques to achieve satisfactory electrical properties. Mechanical design enables deployable antenna structures necessary for satellite applications (e.g., ESA ERS-1). The slotted waveguide concept provides high aperture efficiency, good beamshaping capabilities, and low losses. These CFRP waveguide antennas feature low mass, high accuracy and stiffness, and can be operated within wide temperature ranges. Author

**N87-17236#** Geological Survey of India, Jaipur. Photogeology and Remote Sensing Div.
**COMPARATIVE STUDY OF LANDSAT MSS, SALYUT-7 (TERRA) AND RADAR (SIR-A) IMAGES FOR GEOLOGICAL AND GEOMORPHOLOGICAL APPLICATIONS: A CASE STUDY FROM RAJASTHAN AND GUJARAT, INDIA**
P. C. BAKLIWAL *In* ESA Proceedings of the 1986 International Geoscience and Remote Sensing Symposium (IGARSS '86) on Remote Sensing: Today's Solutions for Tomorrow's Information Needs, Volume 1 p 449-452 Aug. 1986
Avail: NTIS HC A99/MF E03; ESA, Paris, France, 3 volume set $90 Member States, AU, CN, and NO (+20% others)

Rajasthan and Gujarat provinces of India were surveyed using the MKF-6 multispectral and KATE-140 stereo space photographs collected during TERRA experiment and SIR-A radar data acquired during the flight of Columbia Space Shuttle on Nov. 12, 1981. A comparative evaluation of these data for geological applications indicates that lithological discrimination is possible from SIR-A due to differential surface roughness and from KATE-140 due to stereo vision. Structural elements on SIR-A and KATE-140 are better interpreted. Radar data is most suitable for different surface covers and thus provides better details for geomorphic mapping. It is also found that MKF-6 and LANDSAT MSS data provide better data on geomorphology in decreasing order; KATE-140 provides altitude variations and is, therefore, most helpful in pediplain areas. ESA

**N87-17847*#** National Aeronautics and Space Administration, Washington, D.C.
**MPD ARCJET SYSTEM**
K. KURIKI Feb. 1987 34 p Transl. into ENGLISH from Japan Society for Aeronautical and Space Sciences Journal (Japan), v. 33, no. 373, 1985 p 88-100 Original language document was announced in IAA as A86-25186 Transl. by Kanner (Leo) Associates, Redwood City, Calif.
(Contract NASW-3541)
(NASA-TM-88581; NAS 1.15:88581; ISSN-0021-4663) Avail: NTIS HC A03/MF A01 CSCL 21H

The current status and future prospects of the magnetoplasmadynamic (MPD) arcjet system are described. Recent research activities on the chemical rocket and electric propulsion are discussed. The characteristics of various MPD arcjet systems including the Komaba-I system developed by the Institute of Space and Astronautical Science of the Tokyo University are analyzed. The applications of the MPD arcjet system to the satellite test, lunar mission, free flyer test, space station test, and heliospheric exploration are discussed. Author

**N87-17848*#** Rockwell International Corp., Canoga Park, Calif. Rocketdyne Div.
**SPACE STATION RESISTOJET SYSTEM REQUIREMENTS AND INTERFACE DEFINITION STUDY Interim Report**
BRUCE J. HECKERT Feb. 1987 88 p
(Contract NAS3-24658)
(NASA-CR-179581; NAS 1.26:179581; RI/RD87-109) Avail: NTIS HC A05/MF A01 CSCL 21H

Preliminary resistojet design requirements were established based on initial technical requirements imposed by the results of NASA and Rocketdyne studies. The requirements are directed toward long life, simplicity, flexibility, and commonality with other space station components. The resistojet assembly is comprised of eight resistojets, fluid components downstream of the waste fluid storage system, a power controller, structure, and shielding. It consists of two identical subassemblies, one of which is redundant. Each subassembly consists of four 500-W resistojets, series redundant latch values, a power controller, a water vaporizer, two pressure regulators, filters, check valves, disconnects, fluid tubing, and electrical cables. All components are packaged at the end of the stinger aft of the JEM and Columbus modules. Different flow and power control methods were studied. A constant inlet pressure and a two-power setting controller were tentatively selected based on simplicity and reasonably high specific impulse for the range of waste gas compositions that are anticipated. The constant pressure is supplied by pressure regulators. The two set point power control includes individual power supplies to each resistojet heater and water vaporizer. An embedded data processor, a multiplexer-demultiplexer, and a network interface unit that are standard space station components are included in the power controller. The total dry weight of the resistojet assembly is approximately 172 lb. The total cost for design, development, test, evaluation, qualification, and flight hardware is estimated to be $16 million. Author

**N87-18973*#** Management and Technical Services Co., Washington, D.C.
**USSR SPACE LIFE SCIENCES DIGEST, ISSUE 10**
LYDIA RAZRAN HOOKE, MIKE RADTKE, RONALD TEETER, VICTORIA GARSHNEK, and JOSEPH E. ROWE (Library of Congress, Washington, D. C.) Washington NASA Mar. 1987 110 p
(Contract NASW-3676)
(NASA-CR-3922(12); NAS 1.26:3922(12)) Avail: NTIS HC A06/MF A01 CSCL 06C

The USSR Space Life Sciences Digest contains abstracts of 37 papers recently published in Russian language periodicals and bound collections and of five new Soviet monographs. Selected abstracts are illustrated with figures and tables from the original. Additional features include the translation of a book chapter concerning use of biological rhythms as a basis for cosmonaut selection, excerpts from the diary of a participant in a long-term

isolation experiment, and a picture and description of the Mir space station. The abstracts included in this issue were identified as relevant to 25 areas of aerospace medicine and space biology. These areas are adaptation, biological rhythms, biospherics, body fluids, botany, cardiovascular and respiratory systems, developmental biology, endocrinology, enzymology, group dynamics, habitability and environmental effects, hematology, human performance, immunology, life support systems, mathematical modeling, metabolism, microbiology, morphology and cytology, musculosketal system, neurophysiology, nutrition, personnel selection, psychology, and radiobiology. Author

**N87-19441#** National Aerospace Lab., Amsterdam (Netherlands). Space Div.

**RENDEZVOUS AND DOCKING AND SPACE ROBOTICS PROXIMITY OPERATIONS. PART 5: EXECUTIVE SUMMARY Final Report**

J. J. M. PRINS and C. N. A. PRONK 10 Jul. 1985 67 p
(Contract ESA-6060/84)
(NLR-TR-85099-U; ETN-87-99278) Avail: NTIS HC A04/MF A01

In preparation for ESA's Columbus program, test requirements were derived for: full scale testing of final translation (last 10 m) including docking (RVD); full scale testing of any manipulator operations both for free space and during mechanical contact; and scaled testing of fly-around and translation along the docking axis (RVD). Automatic as well as human operator controlled operations need to be tested. ESA

**N87-19442#** National Aerospace Lab., Amsterdam (Netherlands). Space Div.

**SENSORS FOR A SYSTEM TO CONTROL THE LIQUID FLOW INTO AN EVAPORATION COLD PLATE OF A TWO-PHASE HEAT TRANSPORT SYSTEM FOR LARGE SPACECRAFT**

A. A. M. DELIL 4 Jan. 1986 89 p
(Contract NIVR-1073)
(NLR-TR-86001-U; B8679797; ETN-87-99281) Avail: NTIS HC A05/MF A01

Two-phase flow sensors to control liquid flow rates in the Columbus space platform thermal busses were assessed. The hollow core coaxial capacitor concept looks very promising for annular flow and to a lesser extent also for homogeneous flow. Its disadvantage is the extra flow resistance introduced by the gage. The axial capacitor gage is the simplest one. It adds no flow resistance since the electrodes are arranged flush with the flow line wall. Its sensitivity for void fraction variations is better than the corresponding sensitivity of the hollow core coaxial capacitor. A disadvantage is the inability to accurately and sensitively measure in the case of nonannular flow patterns or low void fraction mixtures. Both disadvantages are not very severe. Only in homogeneous flow, the sonic velocity concept offers an alternative to the hollow core coaxial capacitor. The velocity of sound concept is a little more sensitive for the temperature fluctuations since the velocity of sound depends more strongly on the temperature than the permittivity does. ESA

# 19

## GENERAL

Includes descriptions, analyses, trade studies, commercial opportunities, published proceedings, seminars, hearings; historical summaries, policy speeches and statements that have not previously been included.

**A87-10026**

**SPACE CONGRESS, 23RD, COCOA BEACH, FL, APRIL 22-25, 1986, PROCEEDINGS**

Congress sponsored by the Canaveral Council of Technical Societies. Cape Canaveral, FL, Canaveral Council of Technical Societies, 1986, 469 p. For individual items see A87-10027 to A87-10053.

Papers concerned with developing space for tomorrow's society are presented. Consideration is given to international space activities, the use of computers in space, low-cost Shuttle payloads, streamling ground operations, and the commercialization of space. Topics discussed include contracts and management, Space Station technology, the effects of satellites on daily activities, second generation space transportation systems and launch vehicles technology, and the use of robotics and AI in aerospace operations. I.F.

**A87-10043*** National Aeronautics and Space Administration, Washington, D.C.

**TECHNICAL ASPECTS OF THE UNITED STATES SPACE STATION**

D. H. HERMAN (NASA, Washington, DC) and D. BRIEHL IN: Space Congress, 23rd, Cocoa Beach, FL, April 22-25, 1986, Proceedings . Cape Canaveral, FL, Canaveral Council of Technical Societies, 1986, p. 7-1 to 7-6.

The design and development of the Space Station are described. The proposed design of the Station is a dual keel configuration which will include manned facilities and unmanned free flying platforms. The Station is to be utilized as a space-based laboratory for basic research and observations, a depot for repair and servicing of spacecraft, a strorage area, and a manufacturing facility. International participation in the Space Station program and technological developments applicable for the Station are discussed. A diagram of the Space Station configuration and a Space Station development schedule are provided. I.F.

**A87-10875*** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

**SPACE INDUSTRIALIZATION OPPORTUNITIES**

C. M. JERNIGAN, ED. (NASA, Marshall Space Flight Center, Huntsville, AL) and E. PENTECOST, ED. (NASA, Washington, DC) Park Ridge, NJ, Noyes Publications, 1985, 624 p. No individual items are abstracted in this volume.

The current status of efforts to develop commercial space projects is surveyed, with a focus on US programs, in reviews and reports presented at the Second Symposium on Space Industrialization held in Huntsville in February 1984. Areas explored include policy, legal, and economic aspects; communications; materials processing; earth-resources observation; and the role of space carriers and a space station. Also included in the volume are 132 brief descriptions of the NASA Microgravity Science and Applications Program Tasks as of December 1984. These tasks cover the fields electronics materials; solidification of metals, alloys, and composites; fields and transport phenomena; biotechnology; glass and ceramics; combustion science; and experimental technology. T.K.

**A87-14375**

**GETTING BACK ON TRACK IN SPACE**

R. A. LEWIS (Arizona, University, Tucson) and J. S. LEWIS Technology Review (ISSN 0040-1692), vol. 89, Aug.-Sept. 1986, p. 30-40.

The history, current status, and future of the US space program are examined critically from a science perspective. Topics

discussed include the early Soviet lead in heavy boosters, the success of the Apollo program, the lack of an Apollo follow-up program, economic and political factors affecting the decision to concentrate NASA efforts on the Space Shuttle (STS), the abandonment of the Saturn boosters and Skylab, the increasing costs of STS, concomitant decreases in overall NASA funding, military demands on STS, and the slow but continuing progress of the Soviet space program. It is argued that space science objectives would have been and will be better served by a diversified program of mainly unmanned missions than by all-purpose (commercial/military/science) programs such as STS and the proposed Space Station. Recommendations for the future include a long-term program to establish a permanent manned station on Mars, reinvestigation of a solar-power-satellite system, transfer of STS operations to an independent agency, longer-term funding of NASA R&D programs by Congress, competitive development of a new lower-cast heavy-lift launcher, more use of military rockets, and international cooperation on large-scale undertakings. T.K.

**A87-14968*** National Aeronautics and Space Administration, Washington, D.C.
**SPACE STATION - RISKS AND VISION**
K. PEDERSEN (NASA; Georgetown University, Washington, DC) Journal of Space Law, vol. 14, no. 1, 1986, p. 1-13. refs

In assessing the prospects of the NASA Space Station program, it is important to take account of the long term perspective embodied in the proposal; its international participants are seen as entering a complex web of developmental and operational interdependence of indefinite duration. It is noted to be rather unclear, however, to what extent this is contemplated by such potential partners as the ESA, which has its own program goals. These competing hopes for eventual autonomy in space station operations will have considerable economic, technological, and political consequences extending well into the next century. O.C.

**A87-14969**
**THE SPACE STATION - UNITED STATES PROPOSAL AND IMPLEMENTATION**
E. GALLOWAY Journal of Space Law, vol. 14, no. 1, 1986, p. 14-39. refs

NASA's Space Station program has unique technical characteristics which distinguish it from past international space programs; agreements for its establishment must take these features into account. The engineering calculation of adding modules over time should be matched with legal provisions for jurisdiction and control. Attention is presently given to the legal aspects of launching authority, objects launched into outer space, registration of space objects, peaceful and military purposes, exploration and use of the moon, and relationships with the United Nations specialized agencies and other international organizations. O.C.

**A87-15378**
**LOOKING AHEAD FIFTY YEARS IN SPACE**
T. O. PAINE (Thomas Paine Associates, Los Angeles, CA) IN: Space Station beyond IOC; Proceedings of the Thirty-second Annual International Conference, Los Angeles, CA, November 6, 7, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 23-29.
(AAS PAPER 85-453)

A short summary is presented of goals identified by the U.S. National Commission on Space up to 2135, along with desirable missions until 2005. The primary need identified is more routine, cheaper access to space, the latter being a figure of $200 per lb to LEO. A space industrial park is envisioned, initially for testing, development and application of remote sensing instruments. A Space Station in LEO is regarded as a necessary spaceport for transfer orbits to GEO and to more distant goals in the solar system. Other spaceports are needed at a libration point, in a polar lunar orbit and around Mars. M.S.K.

**A87-15387*** National Aeronautics and Space Administration, Washington, D.C.
**THE PLANETARY EXPLORATION PROGRAM - A PREVIEW OF PLANS FOR THE 21ST CENTURY**
J. D. ROSENDHAL (NASA, Office of Space Science and Applications, Washington, DC) IN: Space Station beyond IOC; Proceedings of the Thirty-second Annual International Conference, Los Angeles, CA, November 6, 7, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 111-116.
(AAS PAPER 85-477)

Interplanetary missions which may be pursued in the late 20th and early 21st centuries are discussed, with emphasis on possible roles for the Space Station in the IOC and in growth configurations. The Station could serve as an assembly, fueling and tracking base for interplanetary missions, first unmanned and then manned. M.S.K.

**A87-16109#**
**SPACE TRANSPORTATION - THE KEY TO THE UTILIZATION OF EXTRATERRESTRIAL RESOURCES**
H. H. KOELLE (Berlin, Technische Universitaet, West Germany) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p. refs
(IAF PAPER 86-458)

It is determined that the future exploration of space will require the development of a small, winged aerospace vehicle for transport of people and small payloads to and from a LEO Space Station, and a heavy unmanned launch vehicle for transport of heavy cargo to LEO and cislunar space. A horizontal take-off partially air-breathing vehicle, a single-stage-to-orbit vehicle, and a two-stage rocket plane are proposed for use as a passenger vehicle, and the designs of small and large two-stage fully reusable ballistic vehicles for cargo transport are analyzed. I.F.

**A87-16131#**
**WERNHER VON BRAUN AND COLLIER'S MAGAZINE'S MAN IN SPACE SERIES**
R. LIEBERMANN IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p.
(IAF PAPER 86-497)

A historical account is given of Werher von Braun's contributions to the 'Man in Space Series' of Collier's Magazine in the early 1950s. Three articles by von Braun served as a vehicle with which he was able to break out of the comparative isolation of his technical milieu and appeal to the popular imagination of the U.S. In these articles, von Braun presented ideas for a fleet of reusable Space-Shuttle-type vehicles. A wheel-shaped Space Station was also proposed which would spin to generate gravitation-like centrifugal forces. O.C.

**A87-16136*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**MISSION ANALYSIS AND PHASED DEVELOPMENT OF A LUNAR BASE**
B. B. ROBERTS (NASA, Johnson Space Center, Houston, TX) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 11 p.
(IAF PAPER 86-512)

Manned lunar base activities may support one or more of three basic objectives: scientific research, the exploitation of lunar resources to manufacture a space infrastructure, and the establishment of a self-sufficient lunar base that can serve as a springboard toward long term planetary exploration. The present analysis gives attention to the commonality that may exist among the operational requirements of the three stated goals, as well as the degree of dependency of later developmental phases on the technology and systems development efforts of earlier phases. O.C.

**A87-16137*#** National Aeronautics and Space Administration, Washington, D.C.

**LUNAR SETTLEMENTS - A SOCIO-ECONOMIC OUTLOOK**

B. J. BLUTH (NASA, Space Station Program Office, Washington, DC) IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 1986. 5 p. refs
(IAF PAPER 86-513)

Factors in the design and development of a lunar settlement (LS) which affect the performance of the crew members are discussed. Topics examined include LS-program time constraints imposed by decisions made in developing and operating the Space Station; changes to make allowance for the long-term requirements of LSs; the design of the physical, technical, and organic LS environment; and the vital role of group dynamics in assuring LS success. It is suggested that many short-term cost-minimization strategies employed in spacecraft development may be inappropriate for LS programs. T.K.

**A87-16932*#** National Aeronautics and Space Administration, Washington, D.C.

**THE INTERNATIONAL TEAM**

R. V. LOTTMANN, L. D. WIGBELS (NASA, Washington, DC), and W. E. RICE (NASA, Johnson Space Center, Houston, TX) Aerospace America (ISSN 0740-722X), vol. 24, Sept. 1986, p. 56-58.

In view of the limited resources anticipated for the initial stages of the NASA Space Shuttle program, NASA planners have proposed a multinational partnership concept which will attempt to meet user requirements with minimum duplication of facilities and equipment. A major aspect of this concept is that the assignment of functions to as given country's laboratory module only implies that its subsystems will be tailored as necessary to the accommodation of such functions; the outfitting of the laboratory with research equipment will then be shared by all partners. O.C.

**A87-17996*** National Aeronautics and Space Administration, Washington, D.C.

**THE INTERNATIONAL AEROSPACE INDUSTRY - NEW CHALLENGES AND OPPORTUNITIES FOR TRANSLATION SUPPLIERS**

T. ROWE (NASA, Washington, DC) IN: American Translators Association, Annual Conference, 27th, Cleveland, OH, October 16-19, 1986, Proceedings. Medford, NJ, Learned Information, Inc., 1986, p. 105-109. refs

Attention is given to the recent trend toward internationalization in the aerospace industry and its effects on commercial and governmental translation programs. The aerospace industry, once dominated by organizations from a small number of countries, is now widely international in scope. In effect, there has been in increase in the demand for translations from German, Japanese, Chinese, French and Spanish source material while that for translation from Russian source material has remained constant. The impact of the Challenger disaster on aerospace translation programs is discussed as well as the impact of international participation in Space Station research. K.K.

**A87-18202*** National Aeronautics and Space Administration, Washington, D.C.

**NEW DIRECTIONS IN THE NASA PROGRAM**

U. J. SAKSS and H. J. CLARK (NASA, Washington, DC) IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 3-8.

This paper reports on the current activities of the U.S. National Aeronautics and Space Administration (NASA), and discusses several new directions in NASA's program. The Space Transportation System (STS) is operational and is now performing a wide variety of missions, including repair of spacecraft on orbit. A family of upper stages are available for missions requiring higher energy than the Shuttle alone can provide. With routine access to space assured by the STS, the U.S. is ready to take its next logical step into space with development of a permanently manned Space Station. In addition, NASA is supporting a program for increased commercial development of space through a government-industry partnership. Author

**A87-18203**

**ESA ON-GOING PROGRAMMES AND FUTURE PROSPECTS**

R. MORY (ESA, Directorate of Space Transportation Systems, Paris, France) IN: International Symposium on Space Technology and Science, 14th, Tokyo, Japan, May 27-June 1, 1984, Proceedings . Tokyo, AGNE Publishing, Inc., 1984, p. 9-15.

The current status of ESA space programs is surveyed. Consideration is given to space-science satellites and probes; microgravity projects; terrestrial remote sensing with Meteosat, Earthnet, and ERS-1; telecommunications satellites; the Ariane, Spacelab, and Eureca space transportation systems; and long-term plans for launcher, in-orbit-infrastructure, and manned-space-station development (in cooperation with NASA). T.K.

**A87-18451**

**SPACE EXPLOITATION AND UTILIZATION; PROCEEDINGS OF THE SYMPOSIUM, HONOLULU, HI, DECEMBER 15-19, 1985**

P. M. BAINUM, ED. (Howard University, Washington, DC), K. IKEDA, ED. (Mitsubishi Heavy Industries, Ltd., Tokyo, Japan), T. NOMURA, ED. (Tokyo, University, Japan), T. YAMANAKA, ED. (National Aerospace Laboratory, Tokyo, Japan), G. L. MAY, ED. et al. Symposium organized and sponsored by AAS and Japanese Rocket Society. San Diego, CA, Univelt, Inc. , 1986, 738 p. For individual items see A87-18452 to A87-18470, A87-18472 to A87-18497.

Various papers in the area of space exploitation and utilization are presented. The general topics addressed include: national and international space programs, advanced space-based communications systems, remote sensing of the earth, earth resources satellite technology, future trends in the development of launch vehicle technology, space-based manufacturing, future use of robotic technology for space application, and astrodynamics. C.D.

**A87-18453*** National Aeronautics and Space Administration, Washington, D.C.

**AN OVERVIEW OF NASA'S PROGRAMS AND PLANS**

S. W. KELLER (NASA, Office of Space Science and Applications, Washington, DC) IN: Space exploitation and utilization; Proceedings of the Symposium, Honolulu, HI, December 15-19, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 37-44.
(AAS PAPER 85-647)

An overview is given of NASA's technical program offices and their status, recent accomplishments, and plans for the future. Programs covered include the Space Transportation System, TDRS, the Deep Space Network, the various Spacelab missions, the Galileo mission to Jupiter, the Ulysses mission over the poles of the sun, the Hubble Space Telescope, and the Space Station program. D.H.

**A87-18454*** National Aeronautics and Space Administration, Washington, D.C.

**SPACE STATION - A MODEL FOR FUTURE COOPERATION IN SPACE**

W. P. RANEY (NASA, Office of Space Station, Washington, DC) IN: Space exploitation and utilization; Proceedings of the Symposium, Honolulu, HI, December 15-19, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 47-51.
(AAS PAPER 85-600)

Advances in the ability to operate in, and thus to exploit, space have come more rapidly than almost anything else that has been done. From the beginning, nations have engaged in both cooperation and competition, from the stage of adventurous exploration to the current routine commercial activity. The Space Station program serves as a focus for the free world to move forward together, sharing both risks and benefits during the initial, formative period of an entirely new level of capability. Author

**A87-18455**
**CANADA IN SPACE**
R. W. NEVILLE (Spar Aerospace, Ltd., Mississauga, Canada) IN: Space exploitation and utilization; Proceedings of the Symposium, Honolulu, HI, December 15-19, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 53-70.
(AAS PAPER 85-604)

Canada was the third nation into space and has maintained a position of excellence in technology areas of national significance. The paper examines the factors which have molded Canada's space effort. An historical overview of Canadian space programs provides background for a preview of the major thrusts of future Canadian space activity. Author

**A87-18485**
**AUTOMATION AND ROBOTICS AND THE DEVELOPMENT OF THE SPACE STATION - U.S. CONGRESSIONAL VIEW**
M. L. REISS (U.S. Senate, Washington, DC) IN: Space exploitation and utilization; Proceedings of the Symposium, Honolulu, HI, December 15-19, 1985 . San Diego, CA, Univelt, Inc., 1986, p. 531-538.
(AAS PAPER 85-664)

**A87-18859#**
**PROTECTION OF INTELLECTUAL PROPERTY IN SPACE**
J. L. LANDENBERGER (Booz, Allen and Hamilton, Inc., Bethesda, MD) IN: Aerospace Computer Security Conference, 2nd, McLean, VA, December 2-4, 1986, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1986, p. 80-85. refs
(AIAA PAPER 86-2779)

This paper addresses issues concerning the protection of intellectual property in the space industry, for the Space Shuttle and Space Station. The author defines intellectual property and discuses the current functional and security environments of the Space Shuttle and the proposed Space Station. The protection of intellectual property is defined as a fundamental operational consideration in the Space Shuttle and Space Station because corporations and international users will provide confidential and proprietary data to operating teams and crews in order to conduct onboard experiments. The author also addresses the fact that onboard defense missions require intellectual property protection to protect national security. The paper concludes by identifying methods for improving the protection of intellectual property in the Space Station environment. Author

**A87-21803*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**SPACE STATION INITIATES PERMANENT SPACE FACILITY DEVELOPMENT**
JOSEPH P. LOFTUS, JR. (NASA, Johnson Space Center, Houston, TX) IN: Space nuclear power systems 1985; Proceedings of the Second Symposium, Albuquerque, NM, Jan. 14-16, 1985. Volume 3 . Malabar, FL, Orbit Book Co., Inc., 1987, p. 19-25.

The proposed development of the Space Station is examined. The functions and advantages of the Space Station are described. The use of a solar array system for power generation on the Station is studied; the capabilities of various other generation systems are also evaluated. The Space Station's development schedule is discussed. I.F.

**A87-22721#**
**COST REDUCTION ON LARGE SPACE SYSTEMS THROUGH COMMONALITY**
R. D. WAISS (Boeing Aerospace Co., Seattle, WA) AIAA, Aerospace Sciences Meeting, 25th, Reno, NV, Jan. 12-15, 1987. 9 p. refs
(AIAA PAPER 87-0585)

The need for commonality in large space systems is discussed. The basic goal of a commonality program is to reduce total system cost by maximizing the use of standard and common parts, assemblies, subsystems, and/or systems. The application of commonality to the development, production, deployment, and operations of large space structure is examined. The economic benefits of a commonality approach to large space system development are evaluated. Consideration is given to mandated and nonmandate approaches for implementing commonality. I.F.

**A87-23748**
**SPACE STATION'S UNEASY ALLIANCE**
PETER BACKLUND Space World (ISSN 0038-6332), vol. W-11-275, Nov. 1986, p. 8-10.

The Space Station, NASA's major initiative for the next decade, is described as the agency's most expensive program since the Space Shuttle and the first with no clear end point. NASA is not alone: invitations to participate have been accepted by Japan, Canada and the European Space Agency (ESA). The current negotiations over who will build what seem to be a technical issue but are a preview of what faces the partners in the future, when they tackle such issues as management of the Station, legal and property rights, and division of operational costs. ESA is to provide one of the four attached laboratory modules clustered at the center of the complex, plus a 'free-flying' platform for earth-viewing instruments in polar orbit. Japan will furnish one of the attached modules and Canada will furnish an advanced version of the Shuttle robot arm. ESA has a long-term European Space Plan 'to maintain and develop European independent capabilities in space' with Ariane commanding nearly half the market for commercial launches. These factors have led ESA to get recognition as a 'full junior partner' with the U.S. ESA's proposal to develop a detachable Columbus laboratory is a difficult topic of negotiation with NASA's initial rejection of the concept at first resulting in an impasse. Negotiations resumed when ESA reassured NASA that Columbus would be attached to the Station but would be designed from the start with the capacity to make short duration, man-tended free flyer missions for both U.S. and international users. D.H.

**A87-25443**
**THE CALL FOR PRIVATE INVESTMENT IN THE SPACE STATION**
PETER M. STARK International Space Business Review, vol. 1, July-Aug. 1986, p. 30-33.

Practical advice is given here on various aspects of private investment in the Space Station. The topics considered include: NASA's investment guidelines and comments on them, the wisdom of giving incentives to NASA, insurance and liability, procurement law, venture exclusivity, schedule and funding concerns, and Space Station pricing. Draft NASA guidelines and areas of comment on the guidelines are shown. C.D.

**A87-25752**
**SPACE STATION - DESIGNING THE FUTURE**
ROBERT THOMPSON (McDonnell Douglas Astronautics Co., Saint Louis, MO) IN: Space Tech '86; Proceedings of the International Conference, Geneva, Switzerland, May 14-16, 1986 . London, Online International, Ltd., 1986, p. 9-20.

Requirements for the proposed Space Station, which is to provide permanent life support and housing for an international crew, are examined. The proposed dual-keel design of the Space Station, pressurized cylindrical crew modules, and subsystems (electrical, thermal control, data management, life support control, and propulsion) are described. The Space Station is to be designed to meet users's demands and to be built using a phase development approach. The stages of the phase development are discussed. The basic missions of the Space Station include: (1) science, (2) commercial, (3) technology development, and (4) space operations. Consideration is given to the use of robotic devices on the Station and the development costs. I.F.

**A87-26752**

**THE SEARCH FOR A STABLE REGULATORY FRAMEWORK**

CARL Q. CHRISTOL (Southern California, University, Los Angeles, CA) IN: Tracing new orbits: Cooperation and competition in global satellite development . New York, Columbia University Press, 1986, p. 3-18. refs

Presently existing and possible future legal frameworks for guiding international space activities are summarized. The activities of the ITU and the United Nations COPUOS branch are described, along with major provisions of the 1967 Treaty on Outer Space. Treaty articles which cover the peaceful exploitation of space resources, assign liability for damage arising from space activities, and limit the types of weapons in space are noted. A new international regulatory institution may be needed to resolve and seek solutions to problems such as the accumulation of space debris, the continued commercial development of space in the face of growing military interest in space capabilities, the regulation of international space stations, etc. Finally, limitations on existing agreements governing the exploitation of lunar resources are outlined. M.S.K.

**A87-27455**

**RATIONALISING SPACE STATION**

TIM FURNISS Space (ISSN 0267-954X), vol. 2, Dec. 1986-Feb. 1987, p. 28-30, 36.

Design and applications requirements which are guiding the definition of the configuration for the manned Space Station (MSS) are summarized. A dual-keel design is necessitated by the need to place the modules at the center of gravity to facilitate micro-g materials processing studies. Solar dynamic generators will replace some of the solar panel capacity to reduce drag on the MSS. Several details of the cabin atmosphere, payload servicing accommodations, closed loop operations, and co-orbiting and polar orbiting platform segments of the MSS are outlined, along with design changes in the aftermath of the Challenger catastrophe. M.S.K.

**A87-27815**

**SPACE STATION - MORE SHAKE-UPS AND SCRUB-DOWNS**

CHRIS BULLOCH Interavia (ISSN 0020-5168), vol. 41, Dec. 1986, p. 1415-1417.

An account is given of configurational modifications and changes in construction and development responsibility that have recently been instituted as a result of ongoing Space Station program management studies by NASA. Attention is given to a revision of the Space Station assembly sequence which attempts to spread out Space Shuttle payload lofting schedules; the final configuration of the 'dual-keel' Space Station is not expected to be achieved before the 17th Space Shuttle flight, even with liberal use of expendable launchers in the process. Also discussed are the U.S. Congress' Office of Technology Assessment determinations and recommendations concerning legal and jurisdictional problems in the Space Station program. O.C.

**A87-29401**

**SPACE COMMERCE '86; PROCEEDINGS OF THE INTERNATIONAL CONFERENCE AND EXHIBITION ON THE COMMERCIAL AND INDUSTRIAL USES OF OUTER SPACE, MONTREUX, SWITZERLAND, JUNE 16-20, 1986**

VIVECA C. OTT, ED. Geneva, Interavia Publishing Group, 1986, 489 p. For individual items see A87-29402 to A87-29440.

Progress in the commercialization and industrialization in space is assessed with emphasis on near- and medium-term developments. Details of the history and status of Intelsat and other satellite-based telecommunications systems are explored, along with factors of importance for competing systems, DBS systems, and the evolution of the Intelsat services. NASA, ESA and NASDA efforts to further space industrialization through the Space Station/COLUMBUS program are discussed in great detail. Attention is also given to the encouragement the space agencies are providing to private industries to identify materials processing and other technologies which have the potential for commercial scale manufacturing in space. Spinoffs from space activities which have had significant impacts for terrestrial industries are examined, as are potential and historically proven methods of attracting venture capital to the financing of space projects. The status and prospects for international space law regulating space commercialization are discussed. M.S.K.

**A87-29426*** National Aeronautics and Space Administration, Washington, D.C.

**THE SPACE STATION PROGRAM**

WILLIAM P. RANEY (NASA, Office of Space Station, Washington, DC) IN: Space commerce '86; Proceedings of the International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, June 16-20, 1986 . Geneva, Interavia Publishing Group, 1986, p. 313-318.

Likely configurations and goals of the Space Station are delineated. The Station will be a permanent facility designed to be amenable to evolutionary changes. It will be highly automated and user friendly, will be used to perform basic scientific research and observations and to study technologies and processes that may lead to products manufactured in space, and will allow the repair, refurbishment and launch of satellites. The configuration of the Station is being guided by input from future users, which have already helped identify a need to place the laboratory modules at the center of the station to minimize accelerations imparted by other Station activities. Materials which have commercial potential and can only be produced in space after process definition on the Station are discussed, along with NASA efforts to inform industries of the benefits of participation in the program. M.S.K.

**A87-29427**

**U.S. INDUSTRIAL CONTRIBUTION TOWARDS THE SPACE STATION**

ROBERT W. HAGER (Boeing Aerospace Co., Seattle, WA) IN: Space commerce '86; Proceedings of the International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, June 16-20, 1986 . Geneva, Interavia Publishing Group, 1986, p. 319-324.

U.S. companies are participating in space industrialization by forming design teams to prepare proposals for Space Station designs and manufacture and by conducting research for future space manufacturing. Over 150 contracts are to be issued for various Station systems. Aerospace contractors are spending funds beyond those gained for contract work to enhance their chances for long-term advanced development contracts, which are tabulated to illustrate the scope of the effort. Preparatory work is described which includes the development of hull repair techniques to fix damage from micrometeoroid impacts, low force propulsion systems, AI and robotic systems, etc. NASA is cooperating with industry efforts to identify promising space manufacturing programs through the Centers for Commercial Development of Space. Privately-funded research programs are described which are being undertaken with the knowledge that no payback can be foreseen for at least a decade. M.S.K.

**A87-29435**

**LEASING OF VERSATILE IN-ORBIT INDUSTRIAL SPACE FACILITIES**

WILLIAM A. JOHNSTON, JR. (Fairchild Space Co., Germantown, MD) IN: Space commerce '86; Proceedings of the International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, June 16-20, 1986 . Geneva, Interavia Publishing Group, 1986, p. 415-423.

The considerations which enter into undertaking a commercial space venture are discussed in terms of the LEASECRAFT. A project is initiated after identifying a means to take advantage of the unique aspects of the space environment. LEASECRAFT is a modular, reusable platform for other payloads. Based on the NASA Multimission Modular spacecraft, LEASECRAFT would have standard modules for power, communications and datahandling, attitude control and propulsion. The 15,000 lb platform would stay in orbit permanently, with payload changeout and refurbishment performed by Shuttle crew as needed. Attempts to finance the project are described, including the risk assessments that were

made. Project financing has not been available due to the lack of insurance coverage for the payload. M.S.K.

**A87-29438**
**SPINOFFS FROM THE SPACE PROGRAM - USA (BLIND FAITH OR MONEY IN THE BANK?)**
LEONARD W. DAVID (National Commission on Space, Washington, DC) IN: Space commerce '86; Proceedings of the International Conference and Exhibition on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, June 16-20, 1986 . Geneva, Interavia Publishing Group, 1986, p. 447-451. refs

The history of spinoffs from NASA activities is traced, numerous examples are cited, and possible future spinoffs are explored, including the development of products in space for use in space. NASA efforts to transfer technology to industry since 1961 have, in 25 yr, resulted in the creation of 130,000 jobs and cumulative revenue of about $150 billion. Computer image enhancement techniques developed to enhance planetary photographs are being used to improve X-ray images of internal organs, heat pipes for cooling electronic packages in satellites are installed on the Alaskan oil pipeline, a bone stiffness analyzer used to evaluate Ca loss in long-term spaceflight is being applied to diagnose osteoporosis, etc. The Space Station program will define processes for food production, waste utilization, air regeneration, AI and robotics, and the means by which people from highly diverse cultures can live in a closed environment and work together effectively. The Station is the first step in expanding space industrialization to the moon, Mars and the asteroids. M.S.K.

**A87-29483**
**ANNALS OF AIR AND SPACE LAW. VOLUME 10**
NICOLAS MATEESCO MATTE, ED. (McGill University, Montreal, Canada) Montreal, McGill University, 1985, 626 p. In English and French. For individual items see A87-29484 to A87-29494.

Recent legal developments regarding conventions and treaties which guide the worldwide development of air transportation, civil, commercial and military satellite-based operations, and expanding space station programs are explored. Consideration is given to the assignment of liability for operators of transport terminals, aircraft operators and in Japan. Procedures developed by a neutral state to respond to intrusion into national airspace by a foreign aircraft are discussed. Various European programs to develop multinational DBS and radio broadcast satellites are described, with emphasis on the international implications of transnational media broadcasts. Finally, existing international legal conventions governing space station operations are identified. M.S.K.

**A87-31123*#** National Aeronautics and Space Administration, Washington, D.C.
**NASA'S TECHNOLOGY PLANS - WILL TECHNOLOGY BE READY WHEN WE ARE**
RAYMOND S. COLLADAY (NASA, Office of Aeronautics and Space Technology, Washington, DC) AIAA, NASA, and USAF, Symposium on Automation, Robotics and Advanced Computing for the National Space Program, 2nd, Arlington, VA, Mar. 9-11, 1987. 5 p.
(AIAA PAPER 87-1695)

Recent low NASA science and technology budgets impacted unfavorably on trade balances of aerospace products and lags in several technological areas impinged on other areas already in application which could not be exploited or did not achieve desired performance levels. NASA has formed a Civil Space Technology Initiative, for 1988 start, to foster research on safe and efficient access to space, earth orbiting operations, and science support technologies. R&D programs for fully reusable launch systems, aerobraking concepts, and a multi-arm, highly autonomous capability for space-based remote assembly, repair and servicing of space vehicles are described. Regarding science, emphasis will be placed on large flexible structures and the associated control programs, sensors and data handling and analysis equipment and programs. Finally, technologies common to human activities in regions beyond the Space Station are to be explored in the second phase of the NASA initiative, Pathfinder. M.S.K.

**A87-31137*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**ADVANCED MANNED EARTH-TO-ORBIT VEHICLE**
CHARLES H. ELDRED (NASA, Langley Research Center, Hampton, VA) AAS, Annual Meeting on Aerospace: Century XXI, 33rd, University of Colorado, Boulder, Oct. 26-29, 1986. 15 p. refs
(AAS PAPER 86-407)

Advanced manned launch vehicle concepts which are designed to meet the space transportation architecture and mission needs for the early 21st century are described. Concepts are described which are based both on modest (evolutionary) and revolutionary advancements in performance technologies but with emphasis on defining operations cost. Design options feature fully reusable, vertical-takeoff, horizontal-landing, rocket-powered concepts and include a variety of possible staging arrangements depending on the desired mission emphasis and the available technologies. Author

**N87-10773#** Committee on Appropriations (U.S. Senate).
**DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT—INDEPENDENT AGENCIES APPROPRIATION BILL, 1987**
J. GARN Washington GPO 1986 111 p Report to accompany H.R. 5313 presented by the Committee on Appropriations, 99th Congr., 2nd Sess., 25 Sep. 1986
(S-REPT-99-487) Avail: US Capitol, Senate Document Room

Appropriations for the Department of Housing and Urban Development, and for sundry agencies, boards, commissions, corporations, and offices were discussed for the fiscal year ending September 30, 1987.

**N87-10774#** Committee on Appropriations (U.S. Senate).
**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**
*In its* Department of Housing and Urban Development-Independent Agencies Appropriation Bill, 1987 p 64-70 1986
Avail: US Capitol, Senate Document Room

The appropriations for research, development, and procurement activities of NASA are discussed. B.G.

**N87-10775#** Committee on Science and Technology (U.S. House).
**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION ACT, 1987**
Washington GPO 1986 37 p An act, H.R. 5495, referred to the Committee on Commerce, Science and Transportation, 99th Congress, 2d Session, 30 Sep. 1986
Avail: US Capitol, House Document Room

Appropriations are discussed for research and development; space flight, control, and data communication; construction of facilities; and research and program management by NASA. B.G.

**N87-10982#** Erno Raumfahrttechnik G.m.b.H., Bremen (West Germany).
**COMPOSITES DESIGN HANDBOOK FOR SPACE STRUCTURE APPLICATIONS. EXECUTIVE SUMMARY Final Report**
Paris ESA Sep. 1985 6 p
(Contract ESTEC-5816/84-NL-PB(SC))
(ESA-CR(P)-2196; ETN-86-98082) Avail: NTIS HC A02/MF A01

The ESA composites design handbook is divided into eight main chapters. These chapters are entitled: Handbook organization and user instructions; Material properties and applications; Calculation methods of laminates; General design aspects; Load transfer and design of joints; Structural design; Integrity control; and Verification guidelines. ESA

**N87-11640#** Committee on Science and Technology (U.S. House).

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION ACT, 1987**

Washington GPO 1986 251 p Report to accompany H.R. 5495 presented by the Committee on Science and Technology to the Committee of the Whole House on the State of the Union, 99th Congress, 2d Session, 16 Sep. 1986

(H-REPT-99-829; GPO-58-629) Avail: US Capitol, House Document Room

Authorization of appropriations to the National Aeronautics and Space Administration for the fiscal year 1987 for research and development; space flight, control, and data analysis; construction of facilities; and research and program management is discussed. B.G.

**N87-11641#** Committee on Commerce, Science, and Transportation (U.S. Senate).

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION BILL, 1986**

1986 26 p A bill, H.R. 5495, referred to the Committee on Science and Technology, 99th Congress, 2d Session, 10 Sep. 1986

(H-REPT-99-829) Avail: US Capitol, House Document Room

Authorized appropriations are summarized for the National Aeronautics and Space Administration for the following: permanently manned space station; space transportation capability development; physics and astronomy; life sciences; planetary exploration; solid earth observations; environmental observations; materials processing in space; communications; information systems; technology utilization; commercial use of space; transatmospheric research and technology; tracking and data advanced systems; space flight, control, and data communication; construction of facilities, including land acquisitions; and research and program management. B.G.

**N87-12384*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**STRATEGIC PLAN, 1985**

1985 33 p

(NASA-TM-89263; NAS 1.15:89263) Avail: NTIS HC A03/MF A01 CSCL 05A

The Lewis Strategic Plan was updated for 1985 and beyond. Major programs for the space station, the advanced turboprop, the Advanced Communications Technology Satellite (ACTS), and the Altitude Wind Tunnel were begun or greatly expanded during 1984. In parallel, The Lewis aeropropulsion research and technology program was extensively evaluated and reviewed; a reduced and reoriented program emerged. The thrusts and implementation plans for these programs are described as they pertain to the individual directorates. Other key accomplishments and plans are summarized. B.G.

**N87-12402#** Committee on Science and Technology (U.S. House).

**HEARINGS BEFORE THE SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS OF THE COMMITTEE ON SCIENCE AND TECHNOLOGY, 99TH CONGRESS, 2ND SESSION, NO. 132, 25, 27 FEBRUARY; 11, 13, 20 MARCH; 9, 10 APRIL, 1986, VOLUME 2**

1986 799 p

(GPO-61-777) Avail: US Capitol, House Document Room

The National Aeronautics and Space Administration fiscal year 1987 budget is examined. The impact of the loss of the Challenger and its crew on the space program is assessed. B.G.

**N87-12574#** Committee on Science and Technology (U.S. House).

**NATIONAL COMMISSION ON SPACE REPORT**

1986 76 p Hearing before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, 99th Congress, 2d Session, No. 129, 22 Jul. 1986

(GPO-63-143) Avail: Subcommittee on Space Science and Applications

The National Commission on Space was established by Congress in 1984 to formulate a long range agenda for U.S. civilian space activity, so long range goals, opportunities, and policy options could be identified. The process which the Commission followed to arrive at its conclusions, what those conclusions were, as well as the alternatives that were considered are discussed. The objectives and the financial projection requested to achieve them are examined. B.G.

**N87-14394#** European Space Agency, Paris (France).

**PROCEEDINGS OF AN INTERNATIONAL SYMPOSIUM ON FLUID DYNAMICS AND SPACE**

W. R. BURKE, comp. Aug. 1986 205 p Symposium held in Rhode-Saint-Genese, Belgium, 25-26 Jun. 1986; organized by ESA, and the Von Karman Inst. for Fluid Dynamics

(ESA-SP-265; ISSN-0379-6566; ETN-87-98893) Avail: NTIS HC A10/MF A01

Reentry aerothermodynamics; rocket engines; spacecraft environments; and fluid dynamic experiments in space were discussed. ESA

**N87-15028#** Committee on Commerce, Science, and Transportation (U.S. Senate).

**REPORT OF THE NATIONAL COMMISSION ON SPACE**

Washington GPO 1986 53 p Hearing before the Subcommittee on Science, Technology and Space of the Committee on Commerce, Science and Transportation, 99th Congress, 2nd Session, 22 Jul. 1986

(S-HRG-99-954; GPO-64-727) Avail: Subcommittee on Science, Technology and Space

The proposed agenda for the civilian space program for the next 20 years and beyond was discussed. The National Commission on Space proposed a broad, long-range, pioneering mission which includes: exploration and development of the space frontier; advancing science, technology, and enterprise; and building institutions and systems that make acessible vast resources and support human settlement beyond Earth orbit, from the highlands of the Moon to the plains of Mars. To accomplish this mission, three mutually-supportive thrusts are outlined: advancing scientific understanding of the planet Earth, the solar system, and the universe; exploring, prospecting, and settling the solar system; and stimulating space enterprise. B.G.

**N87-15034*#** National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

**RESEARCH AND TECHNOLOGY, FISCAL YEAR 1986, MARSHALL SPACE FLIGHT CENTER Annual Report**

Nov. 1986 138 p

(NASA-TM-86567; NAS 1.15:86567) Avail: NTIS HC A07/MF A01 CSCL 05A

The Marshall Space Flight Center is continuing its vigorous efforts in space-related research and technology. Extensive activities in advanced studies have led to the approval of the Orbital Maneuvering Vehicle as a new start. Significant progress was made in definition studies of liquid rocket engine systems for future space transportation needs and the conceptualization of advanced laucnch vehicles. The space systems definition studies have brought the Advanced X-ray Astrophysics Facility and Gravity Probe-B to a high degree of maturity. Both are ready for project implementation. Also discussed include significant advances in low gravity sciences, solar terrestrial physics, high energy astrophysics, atmospheric sciences, propulsion systems, and on the critical element of the Space Shuttle Main Engine in particular. The goals of improving the productivity of high-cost repetitive operations on

reusable transportation systems, and extending the useful life of such systems are examined. The research and technology highlighted provides a foundation for progress on the Hubble Space Telescope, the Space Station, all elements of the Space Transportation System, and the many other projects assigned to this Center. Author

**N87-15239*** National Aeronautics and Space Administration, Washington, D.C.
**TECHNOLOGY FOR LARGE SPACE SYSTEMS: A BIBLIOGRAPHY WITH INDEXES (SUPPLEMENT 15)**
Jan. 1987 161 p
(NASA-SP-7046(15); NAS 1.21:7046(15)) Avail: NTIS HC A08 CSCL 22A

This bibliography lists 594 reports, articles and other documents introduced into the NASA scientific and technical information system between January 1, 1986 and June 30, 1986. Its purpose is to provide helpful information to the researcher, manager, and designer in technology development and mission design according to system, interactive analysis and design, structural and thermal analysis and design, structural concepts and control systems, electronics, advanced materials, assembly concepts, propulsion, and solar power satellite systems. Author

**N87-15898#** National Academy of Public Administration, Washington, D. C.
**NASA: THE VISION AND THE REALITY**
ERASMUS H. KLOMAN Oct. 1985 66 p
(OP-5) Avail: NTIS HC A04/MF A01

The complex of aspirations and national priorities lying behind the original vision of the civilian space program and how that program has fared in the real world of politics centering on Washington were explored. The programmatic evolution of NASA and some of the key administrative and management concepts developed to govern the operation of the agency were examined. In gathering information, both former and present NASA officials were interviewed as well as knowledgable individuals outside the agency. B.G.

**N87-15908#** Committee on Appropriations (U.S. Senate).
**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**
*In its* Department of Housing and Urban Development, and Certain Independent Agencies Appropriations for Fiscal Year 1987, Part 2 p 985-1065 1986
Avail: Subcommittee of the Committee on Appropriations

The budget request, along with its necessary revisions, will assist in the initiation of procurement for a replacement orbiter and inertial upper-stage airborne support equipment. Also included are funds to augment activities directed toward resolution of space shuttle sytem anomalies and initiation of development of the Space Station. B.G.

**N87-15986#** Naval Postgraduate School, Monterey, Calif.
**ALFRED THAYOR MAHAN AND SPACE: A NECESSARY UNITY M.S. Thesis**
MARK T. SANDVIGEN Jun. 1986 112 p
(AD-A174007) Avail: NTIS HC A06/MF A01 CSCL 22A

This thesis is an unclassified examination from a Western perspective, of the current and projected space efforts of the world and how they effect current U.S. Space Policy. There is currently no universally accepted space strategy to help in meeting the policy goals of the United States. It is the hypothesis of this thesis that the strategies needed to deal effectively with future space development were layed down in the past by Alfred Thayor Mahan and others. In order to outline a current strategy an analysis was conducted of current space programs, future space efforts, orbitology/orbital mechanics, and the writings of H. Jomini, A. T. Mahan, and Sir Julian Corbett. In order to manage and arrange the large knowledge base, a systems model was developed and used in this analysis. Upon the completion of the analyses, a blending of the Mahan and orbital mechanics was conducted in order to show, by analogy, that there exist parallels between that of naval strategy and strategies needed to reach US policy goals. GRA

**N87-15988#** Joint Publications Research Service, Arlington, Va.
**DETAILS OF CURRENT SPACE DEVELOPMENT PLAN DESCRIBED**
*In its* Japan report: Science and Technology (JPRS-JST-86-018) p 1-24 2 Jul. 1986 Transl. into ENGLISH from Koku Tenbo (Tokyo, Japan), 1985 p 489-508
Avail: NTIS HC A05/MF A01

The current Space Development Plan (enacted 13 March 1985) was formed in response to needs by reviewing the previous Space Development Plan in consideration of the progress of domestic research and development, changes in the international environment, and the long-range outlook concerning the uses of space development. The Space Development Plan (13 March 1985) is outlined. B.G.

**N87-16014*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
**NASA/DOD CONTROL/STRUCTURES INTERACTION TECHNOLOGY, 1986**
ROBERT L. WRIGHT, comp. Nov. 1986 549 p Conference held in Norfolk, Va., 18-21 Nov. 1986; sponsored by NASA Langley Research Center and AFWAL
(NASA-CP-2447-PT-1; L-16242-PT-1; NAS 1.55:2447-PT-1)
Avail: NTIS HC A23/MF A01 CSCL 22B

Control/structures interactions, deployment dynamics and system performance of large flexible spacecraft are discussed. Spacecraft active controls, deployable truss structures, deployable antennas, solar power systems for space stations, pointing control systems for space station gimballed payloads, computer-aided design for large space structures, and passive damping for flexible structures are among the topics covered.

**N87-16551#** Naval Postgraduate School, Monterey, Calif.
**AN INTRODUCTION TO ARTIFICIAL INTELLIGENCE AND ITS POTENTIAL USE IN SPACE SYSTEMS M.S. Thesis**
GARY W. MCDONALD Jun. 1986 129 p
(AD-A174250) Avail: NTIS HC A07/MF A01 CSCL 22B

This survey of Artificial Intelligence (AI) is based upon a review of its history, its philosophical development, and subcategories of its current technologies. These subcategories are expert systems, natural language processing, computer vision and pattern recognition, and robotics and autonomous vehicles. Emphasis is then directed toward the description of the fundamental characteristics of a generic space system, including the space bus components, mission system components, ground node functions, and system missions. It is concluded that AI, in site of its immaturity as a science, will prove to be a beneficial component of future space systems. GRA

**N87-16662#** Executive Office of the President, Washington, D.C.
**AERONAUTICS AND SPACE REPORT OF THE PRESIDENT: 1985 ACTIVITIES**
1986 132 p
Avail: NTIS HC A07/MF A01

The achievements of aeronautics and space programs in the United States for 1985 are summarized in the areas of communications; Earth atmosphere, environment, and resources; space science; space transportation; commercial use of space; space tracking and data systems; space station; and aeronautics and space research and technology. The achievements of each of the following organizations are described: National Aeronautics and Space Administration, Department of Defense, Department of Commerce, Department of Energy, Department of the Interior, Department of Agriculture, Federal Communications Commission, Department of Transportation, Environmental Protection Agency, National Science Foundation, Smithsonian Institution, Department of State, Arms Control and Disarmament Agency, and United States Information Agency. Appendices provide historical information on

launches, satellites, manned and unmanned spacecraft, and federal budgets for aeronautical and astronautical activities. J.P.B.

**N87-16856*#** National Aeronautics and Space Administration, Washington, D.C.
**A NEW DAY: CHALLENGER AND SPACE FLIGHT THEREAFTER**
JESCO VONPUTTKAMER Mar. 1986 18 p Transl. into ENGLISH of 'Ein Neuer Tag: Challenger und die Raumfahrt Danach" Washington, D.C., 11 Feb. 1986 p 1-11
(Contract NASW-4005)
(NASA-TM-77717; NAS 1.15:77717) Avail: NTIS HC A02/MF A01 CSCL 22A

On January 28, 1986, at an altitude of 14 kilometers, the Space Shuttle Challenger was torn apart by an explosion of the external tank. The effects of the accident are undoubtedly far-reaching; they have broad repercussions that affect NASA's international partner organizations. The effects of the postponed shuttle flights on European space programs are discussed. A review of the German participation in the American space program is presented. The need to continue the future projects such as the space station is examined in light of its importance as a springboard for further exploration. B.G.

**N87-17656*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
**RESEARCH AND TECHNOLOGY Annual Report, 1986**
1986 103 p
(NASA-TM-88868; NAS 1.15:88868) Avail: NTIS HC A06/MF A01 CSCL 05A

The research and technology accomplishments of the NASA Lewis Research Center are summarized for the fiscal year 1986, the 45th anniversary year of the Center. Five major sections are presented covering: aeronautics, aerospace technology, space communications, space station systems, and computational technology support. A table of contents by subjects was developed to assist the reader in finding articles of special interest. Author

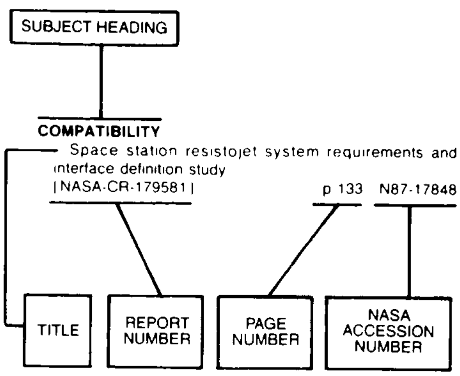
**N87-17799*#** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
**BUDGET AVAILABILITY**
KELLEY J. CYR *In* NASA. Marshall Space Flight Center Manned Mars Mission. Working Group Papers, V. 2, Sect. 5, App. p 929-935 May 1986
Avail: NTIS HC A24/MF A01 CSCL 05C

A forecast of the total NASA budget required to achieve a manned mission to Mars at around the end of this century is described. A methodology is presented for projecting the major components of the NASA budget, including the NASA base, space flight, space station, Shuttle Derived Launch Vehicle, and the Manned Mars Mission. The NASA base, including administrative expenses, construction of facilities and research and development other than manned flight, is assumed to level off at the present (1985) level and remain constant at approximately $3.5 billion (constant fiscal year 1985 dollars). The budget for space flight, which consists of Shuttle research and development, operations, and tracking and data acquisition costs, is projected to decrease from approximately $4 billion in 1985 to just under $2.5 billion by 1989 and then level off. Planning profiles for three major programs are constructed: a permanently manned space station; a Shuttle Derived Vehicle; and a Manned Mars Mission. It is concluded that all of the programs can be conducted by the year 2002 with a 3 percent real growth rate in the NASA budget. Author

**N87-20061*#** National Aeronautics and Space Administration, Washington, D.C.
**NASA OAST AND ITS ROLE IN SPACE TECHNOLOGY DEVELOPMENT**
J. ROMERO *In* JPL, Space Technology Plasma Issues in 2001 p 29-37 1 Oct. 1986
Avail: NTIS HC A20/MF A01 CSCL 12B

Several new programs, efforts in space research and technology, are introduced that the Office of Aeronautics and Space Technology has begun to support. The four key issues that currently are consuming NASA's energies and should be of great concern are listed. NASA is placing its emphasis in space on: (1) reconstituting the Shuttle capability; (2) maintaining the space station momentum; (3) resolving the current science mission backlog; and (4) rebuilding the technology base. Ways of implementing and funding these issues are discussed. E.R.

## Typical Subject Index Listing




The subject heading is a key to the subject content of the document. The title is used to provide a description of the subject matter. When the title is insufficiently descriptive of the document content, the title extension is added, separated from the title by three hyphens. The (NASA or AIAA) accession number and the page number are included in each entry to assist the user in locating the abstract in the abstract section. If applicable, a report number is also included as an aid in identify the document. Under any one subject heading, the accession numbers are arranged in sequence with the AIAA accession numbers appearing first.

# A

# C

# E

# F

# H

# M

# S

# T

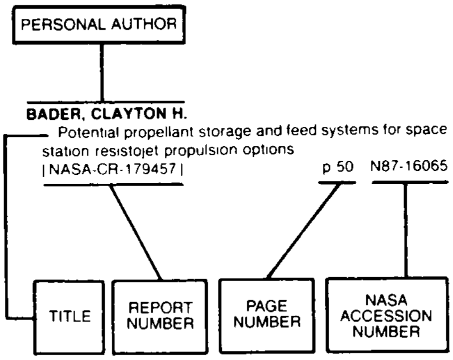
# U

# X

# PERSONAL AUTHOR INDEX



**Typical Personal Author Index Listing**




Listings in this index are arranged alphabetically by personal author. The title of the document provides the user with a brief description of the subject matter. The report number helps to indicate the type of document listed (e.g. NASA report, translation, NASA contractor report). The page and accession numbers are located beneath and to the right of the title. Under any one author's name the accession numbers are arranged in sequence with the AIAA accession numbers appearing first.

## A



AUTHOR

# E



# F

## G

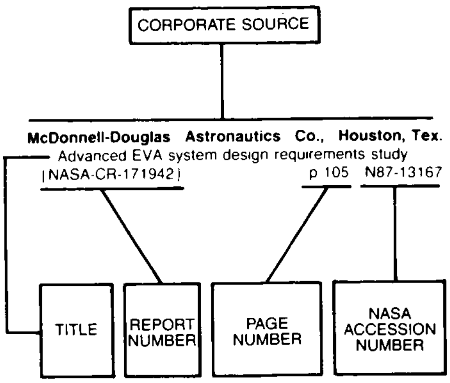
# L

# O



# P

## Typical Corporate Source Index Listing




Listings in this index are arranged alphabetically by corporate source. The title of the document is used to provide a brief description of the subject matter. The page number and the accession number are included in each entry to assist the user in locating the abstract in the abstract section. If applicable, a report number is also included as an aid in identifying the document.

## A



## B



## C



SOURCE

## T



## U



## V

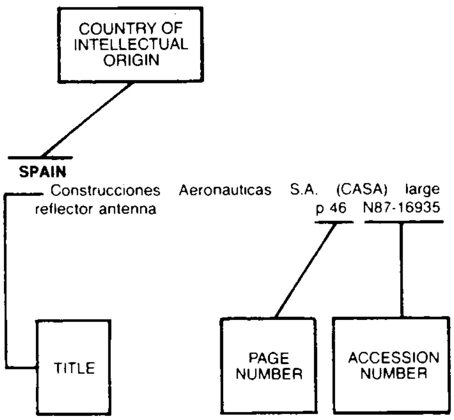


## W



## Y

## Typical Foreign Technology Index Listing




Listings in this index are arranged alphabetically by country of intellectual origin. The title of the document is used to provide a brief description of the subject matter. The page number and the accession number are included in each entry to assist the user in locating the citation in the abstract section.



FOREIGN

## J

### JAPAN



## N

### NETHERLANDS



## S

### SPAIN



### SWEDEN



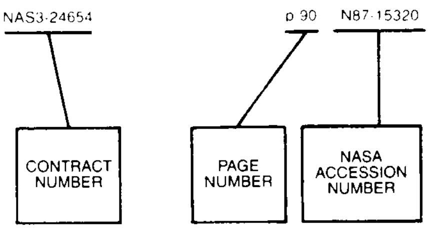
### SWITZERLAND



## U

### USSR

### Typical Contract Number Index Listing

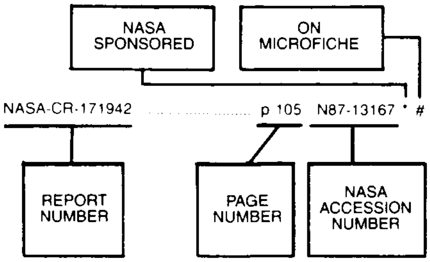



Listings in this index are arranged alpha-numerically by contract number. Under each contract number, the accession numbers denoting documents that have been produced as a result of research done under that contract are arranged in ascending order with the AIAA accession numbers appearing first. The accession number denotes the number by which the citation is identified in the abstract section. Preceding the accession number is the page number on which the citation may be found.



CONTRACT

### Typical Report Number Index Listing




Listings in this index are arranged alpha-numerically by report number. The page number indicates the page on which the citation is located. The accession number denotes the number by which the citation is identified. An asterisk (*) indicates that the item is a NASA report. A pound sign (#) indicates that the item is available on microfiche.

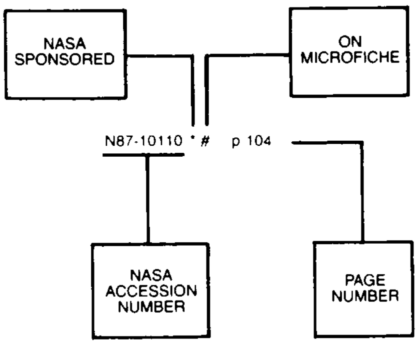


R
E
P
O
R
T

# ACCESSION NUMBER INDEX



### Typical Accession Number Index Listing




Listings in this index are arranged alpha-numerically by accession number. The page number listed to the right indicates the page on which the citation is located. An asterisk (*) indicates that the item is a NASA report. A pound sign (#) indicates that the item is available on microfiche.

# AVAILABILITY OF CITED PUBLICATIONS

**IAA ENTRIES (A87-10000 Series)**

Publications announced in *IAA* are available from the AIAA Technical Information Service as follows: Paper copies of accessions are available at $10.00 per document (up to 50 pages), additional pages $0.25 each. Microfiche[1] of documents announced in *IAA* are available at the rate of $4.00 per microfiche on demand. Standing order microfiche are available at the rate of $1.45 per microfiche for *IAA* source documents and $1.75 per microfiche for AIAA meeting papers.

Minimum air-mail postage to foreign countries is $2.50. All foreign orders are shipped on payment of pro-forma invoices.

All inquiries and requests should be addressed to: Technical Information Service, American Institute of Aeronautics and Astronautics, 555 West 57th Street, New York, NY 10019. Please refer to the accession number when requesting publications.

**STAR ENTRIES (N87-10000 Series)**

One or more sources from which a document announced in *STAR* is available to the public is ordinarily given on the last line of the citation. The most commonly indicated sources and their acronyms or abbreviations are listed below. If the publication is available from a source other than those listed, the publisher and his address will be displayed on the availability line or in combination with the corporate source line.

Avail: NTIS. Sold by the National Technical Information Service. Prices for hard copy (HC) and microfiche (MF) are indicated by a price code preceded by the letters HC or MF in the *STAR* citation. Current values for the price codes are given in the tables on NTIS PRICE SCHEDULES.

Documents on microfiche are designated by a pound sign (#) following the accession number. The pound sign is used without regard to the source or quality of the microfiche.

Initially distributed microfiche under the NTIS SRIM (Selected Research in Microfiche) is available at greatly reduced unit prices. For this service and for information concerning subscription to NASA printed reports, consult the NTIS Subscription Section, Springfield, Va. 22161.

NOTE ON ORDERING DOCUMENTS: When ordering NASA publications (those followed by the * symbol), use the N accession number. NASA patent applications (only the specifications are offered) should be ordered by the US-Patent-Appl-SN number. Non-NASA publications (no asterisk) should be ordered by the AD, PB, or other *report number* shown on the last line of the citation, not by the N accession number. It is also advisable to cite the title and other bibliographic identification.

Avail: SOD (or GPO). Sold by the Superintendent of Documents, U.S. Government Printing Office, in hard copy. The current price and order number are given following the availability line. (NTIS will fill microfiche requests, as indicated above, for those documents identified by a # symbol.)

(1) A microfiche is a transparent sheet of film, 105 by 148 mm in size containing as many as 60 to 98 pages of information reduced to micro images (not to exceed 26.1 reduction).

Avail: BLL (formerly NLL): British Library Lending Division, Boston Spa, Wetherby, Yorkshire, England. Photocopies available from this organization at the price shown. (If none is given, inquiry should be addressed to the BLL.)

Avail: DOE Depository Libraries. Organizations in U.S. cities and abroad that maintain collections of Department of Energy reports, usually in microfiche form, are listed in *Energy Research Abstracts.* Services available from the DOE and its depositories are described in a booklet, *DOE Technical Information Center - Its Functions and Services* (TID-4660), which may be obtained without charge from the DOE Technical Information Center.

Avail: ESDU. Pricing information on specific data, computer programs, and details on ESDU topic categories can be obtained from ESDU International Ltd. Requesters in North America should use the Virginia address while all other requesters should use the London address, both of which are on the page titled ADDRESSES OF ORGANIZATIONS.

Avail: Fachinformationszentrum, Karlsruhe. Sold by the Fachinformationszentrum Energie, Physik, Mathematik GMBH, Eggenstein Leopoldshafen, Federal Republic of Germany, at the price shown in deutschmarks (DM).

Avail: HMSO. Publications of Her Majesty's Stationery Office are sold in the U.S. by Pendragon House, Inc. (PHI), Redwood City, California. The U.S. price (including a service and mailing charge) is given, or a conversion table may be obtained from PHI.

Avail: NASA Public Document Rooms. Documents so indicated may be examined at or purchased from the National Aeronautics and Space Administration, Public Documents Room (Room 126), 600 Independence Ave., S.W., Washington, D.C. 20546, or public document rooms located at each of the NASA research centers, the NASA Space Technology Laboratories, and the NASA Pasadena Office at the Jet Propulsion Laboratory.

Avail: Univ. Microfilms. Documents so indicated are dissertations selected from *Dissertation Abstracts* and are sold by University Microfilms as xerographic copy (HC) and microfilm. All requests should cite the author and the Order Number as they appear in the citation.

Avail: US Patent and Trademark Office. Sold by Commissioner of Patents and Trademarks, U.S. Patent and Trademark Office, at the standard price of $1.50 each, postage free. (See discussion of NASA patents and patent applications below.)

Avail: (US Sales Only). These foreign documents are available to users within the United States from the National Technical Information Service (NTIS). They are available to users outside the United States through the International Nuclear Information Service (INIS) representative in their country, or by applying directly to the issuing organization.

Avail: USGS. Originals of many reports from the U.S. Geological Survey, which may contain color illustrations, or otherwise may not have the quality of illustrations preserved in the microfiche or facsimile reproduction, may be examined by the public at the libraries of the USGS field offices whose addresses are listed in this Introduction. The libraries may be queried concerning the availability of specific documents and the possible utilization of local copying services, such as color reproduction.

Avail: Issuing Activity, or Corporate Author, or no indication of availability. Inquiries as to the availability of these documents should be addressed to the organization shown in the citation as the corporate author of the document.

## PUBLIC COLLECTIONS OF NASA DOCUMENTS

**DOMESTIC:** NASA and NASA-sponsored documents and a large number of aerospace publications are available to the public for reference purposes at the library maintained by the American Institute of Aeronautics and Astronautics, Technical Information Service, 555 West 57th Street, 12th Floor, New York, New York 10019.

**EUROPEAN:** An extensive collection of NASA and NASA-sponsored publications is maintained by the British Library Lending Division, Boston Spa, Wetherby, Yorkshire, England for public access. The British Library Lending Division also has available many of the non-NASA publications cited in *STAR*. European requesters may purchase facsimile copy or microfiche of NASA and NASA-sponsored documents, those identified by both the symbols # and * from ESA – Information Retrieval Service European Space Agency, 8-10 rue Mario-Nikis, 75738 CEDEX 15, France.

## FEDERAL DEPOSITORY LIBRARY PROGRAM

In order to provide the general public with greater access to U.S. Government publications, Congress established the Federal Depository Library Program under the Government Printing Office (GPO), with 50 regional depositories responsible for permanent retention of material, inter-library loan, and reference services. At least one copy of nearly every NASA and NASA-sponsored publication, either in printed or microfiche format, is received and retained by the 50 regional depositories. A list of the regional GPO libraries, arranged alphabetically by state, appears on the inside back cover. These libraries are *not* sales outlets. A local library can contact a Regional Depository to help locate specific reports, or direct contact may be made by an individual.

## ADDRESSES OF ORGANIZATIONS

American Institute of Aeronautics and Astronautics
Technical Information Service
555 West 57th Street, 12th Floor
New York, New York 10019

British Library Lending Division,
Boston Spa, Wetherby, Yorkshire,
England

Commissioner of Patents and Trademarks
U.S. Patent and Trademark Office
Washington, D.C. 20231

Department of Energy
Technical Information Center
P.O. Box 62
Oak Ridge, Tennessee 37830

ESA-Information Retrieval Service
ESRIN
Via Galileo Galilei
00044 Frascati (Rome) Italy

ESDU International, Ltd.
1495 Chain Bridge Road
McLean, Virginia 22101

ESDU International, Ltd.
251-259 Regent Street
London, W1R 7AD, England

Fachinformationszentrum Energie, Physik, Mathematik GMBH
7514 Eggenstein Leopoldshafen
Federal Republic of Germany

Her Majesty's Stationery Office
P.O. Box 569, S.E. 1
London, England

NASA Scientific and Technical Information Facility
P.O. Box 8757
B.W.I. Airport, Maryland 21240

National Aeronautics and Space Administration
Scientific and Technical Information Division (NTT-1)
Washington, D.C. 20546

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Pendragon House, Inc.
899 Broadway Avenue
Redwood City, California 94063

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402

University Microfilms
A Xerox Company
300 North Zeeb Road
Ann Arbor, Michigan 48106

University Microfilms, Ltd.
Tylers Green
London, England

U.S. Geological Survey Library
National Center - MS 950
12201 Sunrise Valley Drive
Reston, Virginia 22092

U.S. Geological Survey Library
2255 North Gemini Drive
Flagstaff, Arizona 86001

U.S. Geological Survey
345 Middlefield Road
Menlo Park, California 94025

U.S. Geological Survey Library
Box 25046
Denver Federal Center, MS914
Denver, Colorado 80225

| 1. Report No. NASA SP-7056 (05) | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| 4. Title and Subtitle Space Station Systems A Bibliography with Indexes | | 5. Report Date November, 1987 |
| | | 6. Performing Organization Code |
| 7. Author(s) | | 8. Performing Organization Report No. |
| | | 10. Work Unit No. |
| 9. Performing Organization Name and Address National Aeronautics and Space Administration Washington, DC 20546 | | 11. Contract or Grant No. |
| | | 13. Type of Report and Period Covered |
| 12. Sponsoring Agency Name and Address | | 14. Sponsoring Agency Code |

15. Supplementary Notes

Compiled by Technical Library Branch and edited by Space Station Office, Langley Research Center, Hampton, Virginia.

16. Abstract

This bibliography lists 967 reports, articles and other documents introduced into the NASA scientific and technical information system between January 1, 1987 and June 30, 1987. Its purpose is to provide helpful information to the researcher, manager, and designer in technology development and mission design according to system, interactive analysis and design, structural and thermal analysis and design, structural concepts and control systems, electronics, advanced materials, assembly concepts, propulsion, and solar power satellite systems. The coverage includes documents that define major systems and subsystems, servicing and support requirements, procedures and operations, and missions for the current and future Space Station.

| 17. Key Words (Suggested by Authors(s)) | 18. Distribution Statement |
|---|---|
| Space Stations<br>Space Platforms<br>Space Technology Experiments<br>Space Erectable Structures | Unclassified - Unlimited |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price * |
|---|---|---|---|
| Unclassified | Unclassified | 248 | A11/HC |

# NTIS PRICE SCHEDULES

(Effective January 1, 1987)

## Schedule A
## STANDARD PRICE DOCUMENTS AND MICROFICHE

| PRICE CODE | PAGE RANGE | NORTH AMERICAN PRICE | FOREIGN PRICE |
|---|---|---|---|
| A01 | Microfiche | $ 6.50 | $13.00 |
| A02 | 001-025 | 9.95 | 19.90 |
| A03 | 026-050 | 11.95 | 23.90 |
| A04-A05 | 051-100 | 13.95 | 27.90 |
| A06-A09 | 101-200 | 18.95 | 37.90 |
| A10-A13 | 201-300 | 24.95 | 49.90 |
| A14-A17 | 301-400 | 30.95 | 61.90 |
| A18-A21 | 401-500 | 36.95 | 73.90 |
| A22-A25 | 501-600 | 42.95 | 85.90 |
| A99 | 601-up | * | * |
| NO1 | | 45.00 | 80.00 |
| NO2 | | 48.00 | 80.00 |

## Schedule E
## EXCEPTION PRICE DOCUMENTS AND MICROFICHE

| PRICE CODE | NORTH AMERICAN PRICE | FOREIGN PRICE |
|---|---|---|
| E01 | $ 7.50 | 15.00 |
| E02 | 10.00 | 20.00 |
| E03 | 11.00 | 22.00 |
| E04 | 13.50 | 27.00 |
| E05 | 15.50 | 31.00 |
| E06 | 18.00 | 36.00 |
| E07 | 20.50 | 41.00 |
| E08 | 23.00 | 46.00 |
| E09 | 25.50 | 51.00 |
| E10 | 28.00 | 56.00 |
| E11 | 30.50 | 61.00 |
| E12 | 33.00 | 66.00 |
| E13 | 35.50 | 71.00 |
| E14 | 38.50 | 77.00 |
| E15 | 42.00 | 84.00 |
| E16 | 46.00 | 92.00 |
| E17 | 50.00 | 100.00 |
| E18 | 54.00 | 108.00 |
| E19 | 60.00 | 120.00 |
| E20 | 70.00 | 140.00 |
| E99 | * | * |

*Contact NTIS for price quote.

## IMPORTANT NOTICE

NTIS Shipping and Handling Charges

U.S., Canada, Mexico — ADD $3.00 per TOTAL ORDER

All Other Countries — ADD $4.00 per TOTAL ORDER

Exceptions — Does NOT apply to:

ORDERS REQUESTING NTIS RUSH HANDLING

ORDERS FOR SUBSCRIPTION OR STANDING ORDER PRODUCTS *ONLY*

NOTE: Each additional delivery address on an order requires a separate shipping and handling charge.